SCIENTIFIC AGRICULTURE

VOLUME 26 JULY, 1946 No. 7

ASPARAGUS SELECTIONS AND CERTAIN CULTURAL PRACTICES COMPARED FOR YIELD, EARLINESS AND SEX RATIOS[1]

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[Received for publication May 16, 1946]

Although considerable experimental work has been done on asparagus, no appreciable improvement has been made during the past twenty-five years. Opinion differs as to the advisability of grading roots at planting time and the discarding of small crowns. A project was begun at the Horticultural Experiment Station, Vineland, Ontario in an attempt to produce a higher yielding strain of Mary Washington asparagus and at the same time to investigate the effect of the size of the root at planting time on the subsequent yield of the plant.

LITERATURE

Breeding

Hexamer (8) in 1901 noted that asparagus varieties lacked uniformity and suggested a method of seed production to maintain variety type by selecting typical high-yielding staminate and pistillate plants in the ratio of 1 male to 4 or 5 females. The following spring the selected plants were permitted to grow without cutting so that they flowered earlier than plants not selected and thus assured the crossing of the more desirable types.

Douglass (2) in Australia stressed the importance of selecting suitable staminate and pistillate plants and isolating them for seed production in the ratio of about 6 pistillate to 1 staminate. He further suggested that the seedlings obtained should be reselected on the basis of yield and type.

Schermerhorn (16), from records on approximately 1,500 asparagus plants, observed that some plants may not produce any spears or only 1 or 2, although others may produce over 100 spears. Some plants could be cut every day while others could only be cut every 2 or 3 weeks. There was considerable variation in the time of first harvest, some plants being cut early in the season, some in mid-season, and others very late in the season. He found that the diameter of the brush in the fall was not a reliable indication of the diameter of spears that may be cut the following spring.

Five year's records of individual asparagus plants as reported by Hanna (5) indicate a wide variation in yield, average weight of spear, cross-section, shape, earliness, compactness of head, and colour.

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To obtain a high-yielding strain of asparagus Young (19) kept individual records on 278 plants for 2 years. Of the 10 highest yielding plants the first year, 5 were males and 5 females, and of the 10 high-yielding plants the second year, 6 had been in the high-yielding 10 the previous year. From this he concluded that it should be possible to obtain high-yielding parent plants which should produce high-yielding progeny.

From records on individual asparagus plants Robb (14) found considerable variation between plants. Some plants tended to be low-yielding and others to be high-yielding each season. A high correlation was shown between early yields and total yields.

Currence and Richardson (1), from 3 years' records on 250 plants grown from commercial seed of the Mary Washington variety, correlated yield and spear size with several other characters as a possible aid in making plant selections. There was a lack of correlation between size of 1-year-old roots and yield for the first 2 years of harvest. There was a significant correlation between early cuttings and yield of the 2 years. The number of stalks and the diameter of 4-year-old plants were significantly correlated with yield and spear size. Both of the correlations with spear size were negative. To obtain information regarding the transmission of yielding ability an individual female plant was crossed with 7 male plants. The production for 2 years on 4 progenies of 11 or more plants each, found 1 of the 4 progenies did not agree with expectations based on yields of the male parent which the authors felt was suggestive of the importance of progeny testing as an aid in selecting for high productivity.

At about the same time as the above work was being done Hanna (6) was attempting to discover how long individual plant records had to be taken in order to be certain of the yielding ability of the plant. He stated that "in general early yielding plants are frequently high yielding at the end of 4 years." On the basis of yields of 5 male plants for 7 years it appeared that 4 years was not sufficient time upon which to judge the yielding ability of the plants. Two of these plants showed a distinct increase in yield as they grew older, 2 others increased their yield slightly, while the remaining plant distinctly decreased in yield and the progeny of crosses of this plant also exhibited this tendency.

In a later paper Hanna (7) reports further data on 139 individual plants and shows correlations of total yields for the first 3 years, the first 5 years, and from the 6-to-8-year period. When all plants were considered, the yields at the end of the 3-year period and the 5-year period were highly correlated with the yield at the end of the 10-year period. This was also the same for the lowest yielding 20% of the plants. The highest yielding 20% showed a lower correlation for these same periods. There was a high correlation between 10-year yields and the 6 to 8-year yields for the high-and-the-low-yielding groups but a low correlation when all plants were considered. He found from the individual plant records that all of the high-yielding plants at the end of 10 years were not high-yielding during the early years and some of the high-yielding plants in the early years later died or were low-yielding at the end of 10 years. Data were also presented to show that in the selection of crowns at planting time neither the diameter of the crown nor the number of buds was a good indication of the future yield of the plant.

A later paper by Young (20) gives 5 years' data on 276 individual plants. He found a correlation of $+.913 \pm .065$ between average number of spears and the number of summer stalks and $+.817 \pm .013$ between yield and number of summer stalks.

Richardson and Currence (12) crossed 3 pistillate plants of similar phenotypic performance with 6 staminate plants 1 of which was phenotypically weaker than the others on the basis of 3-year records on weight, yield, number of spears per plant and average weight of individual spears. Fifty plants each of 18 progenies were grown in individual pots and weight records were taken $2\frac{1}{2}$ months after seeding. The progenies were compared as to number of days from seeding to emergence and weight at $2\frac{1}{2}$ months of age. The variation due to the interaction of staminate and pistillate plants was highly significant in regard to number of days to emergence and significant in regard to the weight of $2\frac{1}{2}$-months old progenies. The variation due to pistillate plants was significant with regard to weight of the progenies and that due to staminate plants was significant with regard to number of days to emergence. There was no significant correlations between any of the parental factors and those of their progenies.

It has long been recognized that astminate plants outyield pistillate plants. Robbins and Jones (13) found that during the first and second seasons of growth after transplanting, staminate plants outyield pistillate plants. They considered that the increased yield was due to greater food manufacturing surface of the staminate plant as compared to the pistillate. Currence and Richardson (1) were unable to show that the roots of staminate plants were inherently more vigorous, so they suggested that differences in production probably are the result of the formation of seeds by the pistillate plants. Haber (4) also found that male crowns produced a greater number of spears and heavier yield per plant than do females. Tiedjens (17) suggested that staminate plants outyield pistillate by 25% and that staminate plants die out sooner than pistillate plants. From a count of nearly 2,000 thirty-five-year-old asparagus plants Yeager and Scott (16) found a ratio of 3.5 staminate to 1 pistillate and they assumed that since the original ratio must have been close to 1 : 1 that apparently the pistillate plants died out sooner than the staminate. They also presented evidence that staminate plants outyield pistillate plants. Rawes (11) in England, from 3 years results, concluded that male plants yielded 60% better than females.

Robbins and Jones (15) investigated the possibility of secondary sex characters in asparagus, and while they were able to show that there were certain differences between staminate and pistillate plants, none of these would be of assistance in separating male and female plants before they flowered. They stated that "*Asparagus officinalis* is normally dioecious. All asparagus flowers are apparently potentially hermaphrodite. During floral development there is, except in rare cases, an abortion of 1 set of sex organs. The following flower forms occur; strongly pistillate, weakly pistillate, hermaphrodite, weakly staminate, and strongly staminate." They found only a very small percentage of true hermaphroditic asparagus plants during the course of the investigations. Norton (10) also found hermaphroditic flowers to be rare. Flory (3) also reported that the occurrence of hermaphroditic flowers was rare and that since these only occurred

on staminate plants suggested that the staminate plants were heterogametic for sex. Rick and Hanna (13) present data to indicate that in asparagus the staminate plants are heterogametic for sex and that sex is inherited in a simple Mendelian manner, maleness being dominant. The occasional seed produced on staminate plants is really the result of male selfiings which segregate in a ratio of 3 males to 1 female plant. A progeny test of the males will indicate those which are homozygous as they produce progenies of all male plants. Since male plants outyield female plants by a considerable amount, a method of producing an all male population would be very desirable. It was suggested that an isolated seed plot be established composed of high-yielding homozygous male plants, which had been determined by a progeny test, and high-yielding female plants. The seed produced from this plot would give an all male population.

Cultural Methods

It has been a general recommendation that asparagus growers should discard small crowns at planting time. Jones and Hanna (9) separated 1-year-old plants into 3 size groups at the time of planting and data on both spear and stalk production were collected for 12 years. They found no relation between size of crown planted and weight of spear or mean number of stalks per plant. The yield of the 3 crown sizes indicated the desirability of discarding the smallest crowns. In his investigations on effect of size of root at planting time on subsequent yield Haber (4) used 150-one-year-old asparagus plants dug in the spring. These roots ranged in weight from 3 to 57 grams. He found no correlation between the weight of crowns and weight and number of spears produced when male and female plants were considered together. There was, however, a significant correlation when only male plants were considered. Currence and Richardson (1) and Hanna (7) from their work suggest that the discarding of the small crowns may eliminate some of the highest yielding plants.

MATERIALS AND METHODS

For this experiment seed was obtained from 5 high-yielding postillate Mary Washington plants which had been isolated with 2 high-yielding staminate plants of the same variety. Individual plant records had been taken on these plants for 3 years by Robb (14). Seed of these 5 selected strains designated as strains 14, 35, 38, 40, and 44 and a commercial strain of the Mary Washington variety of asparagus was planted in the greenhouse in February 1933 and also outside in May 1933. The plants grown inside were transplanted outside at the same time and adjacent to the outside sown seed. Both sets of roots were planted in April 1935 in the permanent location where the soil is classified as Vineland Fine Sandy Loam. At that time the roots of the 6 strains were graded for large size and number of buds, approximately 40% being discarded from each strain. Strain 44 and the commercial strain were included as both graded and ungraded roots. The 6 strains with graded roots and the 2 strains with ungraded roots were considered as 8 different strains and were randomized in eight blocks. The main plots of strains were composed of randomized sub-plots of roots from inside and outside sown seed. A sub-plot consisted of a single row of 12 plants spaced 2 feet in the row and 4 feet between rows.

The first harvest was in 1937 for a period of 4 weeks. In 1938 the length of the cutting season was 6 weeks, in 1939 5 weeks, and in 1940 7 weeks. As far as possible the asparagus was cut when the spears were from 6 to 8 inches long and this usually required that harvesting be done every second day. The total weight of the spears cut from each plot was recorded in grams regardless of the size or grade of the asparagus. At the end of each year the total weight of the asparagus cut from each plot was converted from grams to tons per acre for ease in calculation.

RESULTS

The data were analyzed according to the analysis of variance and the essential information is given in Table 1. The F value for years exceeds the value necessary at the 1% point. It is to be expected that a perennial crop such as asparagus would show a progressive increase in yield as it advances toward maturity. For strains the F value was highly significant and for seeding time it exceeded the 5% point. The F value of 1.46 for the interaction of years and strains approaches the value of 1.64 necessary for significance at the 5% point.

TABLE 1.—ANALYSIS OF VARIANCE OF DATA ON YIELDS IN TONS PER ACRE OF ASPARAGUS RESULTING FROM DIFFERENT STRAINS AND TIMES OF SEEDING

Variation due to	D/F	Mean square	Standard error	F Value
Years	3	20.240817		30.37†
Strains	7	6.866753		13.38†
Replications	7	1.368608		2.66*
Error *(a)*	49	0.514121	0.7170	
Sub-total	53			
Seeding time	1	1.866070		4.77*
Seeding Time × strains	7	0.411288		1.05
Error *(b)*	56	0.391201	0.6254	
Sub-plots	127			
Years × replications	21	0.107887		1.25
Years × strains	21	0.125968		1.46
Error *(c)*	147	0.086504	0.2941	
	255			
Years × seeding time	3	0.016760		
Years × seeding time × strains	21	0.077865		1.10
Error *(d)*	168	0.070718	0.2659	
Total	511			

* Exceeds value for 5% point.
† Exceeds value for 1% point.

YIELDS OF SELECTIONS AND A COMMERCIAL STRAIN OVER A FOUR-YEAR PERIOD

The interaction of years and strains is presented in Table 2 and none of the cross differences was significant. The yields of the various strains remained rather consistent over the 4 years. The yields of the strains the

TABLE 2.—THE YEARLY AND TOTAL YIELDS OF SPEARS IN TONS PER ACRE FROM GRADED ROOTS OF 5 SELECTED STRAINS AND 1 COMMERCIAL STRAIN AND FROM UNGRADED ROOTS OF 2 OF THE SAME STRAINS OF MARY WASHINGTON ASPARAGUS

Strains	1937	1938	1939	1940	Total	Mean
14 Graded	1.92	2.15	2.86	2.74	9.67	2.418
35 Graded	1.96	2.02	2.66	2.85	9.46	2.365
38 Graded	1.83	1.55	2.17	2.22	7.47	1.666
40 Graded	1.67	1.93	2.69	2.65	8.94	2.235
44 Graded	1.33	1.67	2.18	2.19	7.56	1.890
44 Ungraded	1.68	1.87	2.20	2.31	8.66	2.015
Com. graded	1.34	1.57	2.01	2.12	7.04	1.760
Com. ungraded	1.02	1.21	1.78	1.80	5.81	1.452
Total	12.61	13.97	18.55	18.88	64.01	16.003
Mean	1.376	1.746	2.318	2.360	8.001	2.0003
Sig. Difference*	0.20	0.26	0.33	0.39	0.51	0.235

* Minimum difference required for significance at the 5% point.

first year were also closely in line with the total yields for the 4 years. This did not agree with the work of Hanna (7) who found a low correlation between the yields of individual asparagus plants at the end of 3 years and at the end of 10 years. However, this plantation seems to have reached peak production as indicated by strains 14, 40, and 44 which apparently attained maximum production at 3 years.

The yields of the 5 selected strains and the commercial strain as given in Table 3 indicate that these 6 strains may be divided in 2 groups on the basis of yield. The high yielding group of strains 14, 35, and 40 significantly outyielded the lower yielding group comprising strains 38, 44 and the commercial strain. Strain 38 which was the lowest yielding of the selected strains exceeded the yield of the commercial strain by an amount which approaches significance. Since 3 of the 5 selected strains significantly outyielded the commercial strain and the other 2 exceeded that strain by an amount tending to be significant there would seem to be little doubt that the yielding ability of the parent plants was to some degree at least transmitted to the next generation. The performance of the 6 strains in this test would tend to confirm the value of progeny testing as a means of selecting high yielding parent plants as suggested by Currence and Richardson (1). Richardson and Currence (12) working with small progenies found 1 plant out of 4 whose progeny did not agree with expectations based on the performance of the parents. The selected strains on the average exceeded the yield of the commercial strain by about 23% but strain 14, the best of the selected strains, outyielded the commercial strain by 37% or, where the commercial strain was not graded, by over 80%. These distinct differences in yield suggest that asparagus growers should be entitled to expect strains of asparagus which should outyield present strains by at least 50%. The evidence seems definite that while some improvement in asparagus can be expected by isolating superior phenotypes still greater improvement may result from the isolating of superior parent plants by means of the progeny test.

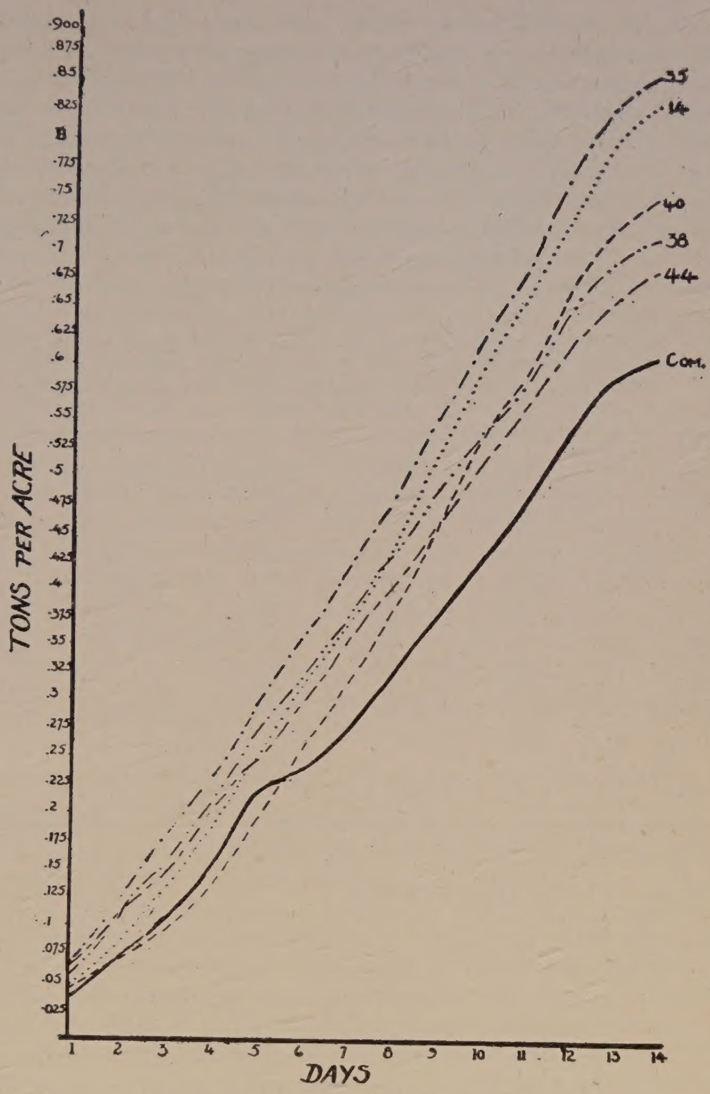

FIGURE 1. The 4-year average yield of 6 strains of asparagus for the initial one-third of the harvest season.

EARLY SEASON YIELD

Since the yield in the early part of the season is an important consideration for either the home or market gardener the 6 strains have been compared in regard to their yielding ability early in the season. The average yields for the 4 years of the 6 strains for the first 2 weeks or approximately the initial one-third of the harvest season are shown in Figure 1. Strain 35 appears to be outstanding as regards early yield as well as total yield and would appear to be more desirable than strain 14 which gave an almost equal total yield. Strain 40 ranked with strains 35 and 14 in total yield but the early yield was very poor. It is of interest that all of the

selected strains have a greater early yield than the commercial strain. While no attempt has been made to correlate early yield and total yield the yielding behaviour of the 6 strains in regard to early and total yields is reasonably similar. This is in agreement with the work of Robb (14) who found a correlation between the early and total seasonal yields of individual plants. While the differences in early yield shown in Figure 1 cannot be tested statistically for significance it would appear quite possible to breed early high-yielding strains. Since the strains having the highest early yield have also a high total yield, a strain or variety combining high early and total yield is an interesting possibility.

TABLE 3.—THE TOTAL YIELD IN TONS PER ACRE OF THE GRADED ROOTS OF 6 STRAINS AND OF THE UNGRADED ROOTS OF 2 OF THE SAME STRAINGS TOGETHER WITH THE PERCENTAGE OF MALE AND FEMALE PLANTS AND A X^2 ANALYSIS OF THE TWO SEXES

Strain	Yield	Males	Females	X^2	P
	Tons per acre	%	%		
14 Graded	9.57	53	47	1.333	0.3 – 0.1
35 Graded	9.46	46	54	1.905	0.2 – 0.1
38 Graded	7.47	48	52	0.424	0.7 – 0.1
40 Graded	8.94	46	54	1.347	0.3 – 0.1
44 Graded	7.56	45	55	2.105	0.2 – 0.1
44 Ungraded	8.06	45	55	2.105	0.2 – 0.1
Com. graded	7.04	52	48	0.266	0.7 – 0.5
Com. ungraded	5.81	40	60	9.186	<0.01
Mean	8.01				
Sig. difference*	0.51				

* Minimum difference required for significance at the 5% point.

ROOT GRADING AS RELATED TO YIELD

The yields of the graded and ungraded roots of strain 44 and the commercial strain are presented in Table 3. The difference in yield in favour of the ungraded roots over the graded roots of strain 44 was 0.50 tons while the minimum difference required for significance was 0.51 tons. The graded roots of the commercial strain significantly outyielded the ungraded roots of the same strain.

If the results of root grading with only strain 44 are considered the data suggest that root grading by discarding the small roots at planting time as a means of eliminating low-yielding plants, may not be justified. Currence and Richardson (1) did not obtain a significant correlation between the weight of 1-year roots and the yield over a 4 year period. Young (20) also concluded that even the most careful selection of roots at planting time would not eliminate poor producing plants. However, Jones and Hanna (9) showed that from 12 years' data with 2 varieties of asparagus, it was desirable to discard small crowns at planting time. In this experiment, the results would tend to suggest that it is desirable to grade the roots at planting time, but in view of the limited scope of the test, and the conflicting evidence of strain 44, further work on the effect of root grading would seem advisable.

From the percentage of male and female plants in Table 3 it is of interest that while the proportions of male and female plants were equal in the plots of graded and ungraded roots of strain 44, the proportions were unbalanced with respect to the corresponding plots of commercial strain. From X^2 tests of the number of staminate and pistillate plants in the plots of graded and ungraded roots of each strain it was evident that all except the plants of ungraded roots of the commercial strain were in agreement with the expected 1 : 1 ratio. Further X^2 tests on plants concerned in this unbalanced ratio indicate that those from greenhouse sown seed were in a 1 : 1 ratio while those from field sown seed were not. A possible explanation is that the male seedlings were weaker and, while able to survive under greenhouse conditions, more male seedlings may have failed to survive in the field. It has been suggested by Tiedjens (17) that staminate plants die out sooner than pistillate although Flory (3) found a 1 : 1 ratio to be expected in asparagus. Male plants outyield female plants as previously stated, and if male plants outyield female plants by as much as 25% as suggested by Tiedjens it is interesting to speculate as to the possible yields of the graded and ungraded roots of the commercial strain if the ratio of male and female plants had been more nearly the same for both strains. However, it is questionable if one could explain all of the differences in yield by the difference in the ratio of male and female plants. The possibility must not be overlooked that grading of the roots may have a differential effect with different strains, and that grading the roots of the commercial strain offered a better opportunity to eliminate weak plants than the grading of the selected strain 44.

Time of Seed Sowing as Related to Yield

The mean yield of the plants produced from seed sown outdoors in May was 1.03 tons per acre and the mean yield of the plants from seed sown in the greenhouse in February was 0.97 tons per acre. Since the F value for seeding time shown in Table 1 is significant at the 5% point it is apparent that the plants from seed sown outside in the usual manner significantly outyielded the plants from seed sown earlier in the greenhouse. Although the plants from both inside and outside sown seed were 2 years old, those which had been started inside were very large at the time of planting in the permanent location. The difference in yield in favour of the outside sown seed may have been due at least in part to the definite check in growth sustained by the large plants from the greenhouse sown seed.

SUMMARY

No appreciable improvement has been made in asparagus since the introduction of the variety Mary Washington 25 years ago. There is no general agreement as to the advisability of grading roots at planting time and discarding small crowns. In 1933 five strains, 14, 35, 38, 40, and 44, the progeny of five high-yielding female plants which had been isolated with two high-yielding male plants, were planted along with a commercial strain of the Mary Washington variety at the Horticultural Experiment Station, Vineland, Ontario. These strains were compared on the basis of yields of 6-to-8-inch spears recorded for 4 years. Some of the main results may be summarized as follows:

1. The five selected strains and the commercial strain could be divided into 2 yield groups with 3 of the selected strains in the high-yielding group and the other 2 selected strains and the commercial strain in the lower-yielding group.

2. The 2 highest-yielding strains were also the highest-yielding for the initial one-third of the harvest season and in general the 6 strains rank in the same order for early and total yield which might indicate a close relationship between early yield and total yield.

3. The results obtained from grading the roots of one selected strain and the commercial strain suggest that in general it is desirable to grade the roots before planting. However, in view of some conflicting evidence and the limited scope of the experiment further work would seem advisable.

4. Sowing seed in the greenhouse in February and transplanting the plants outdoors in May at the usual time of seed sowing produced plants which, when planted in the permanent location as 2-year-old plants, were very large and received a definite check in growth. The plants grown from seed sown in the greenhouse did not yield as much as the plants grown from seed sown outdoors at the usual time of seed sowing.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to Dr. T. M. Currence of the Division of Horticulture, University of Minnesota, for valuable suggestions in the preparation of the paper and to T. N. Hoblyn of East Malling Research Station, England, for his suggestions regarding the layout of the experiment.

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GROWTH STIMULATION IN IRIS BULBS BY UREA[1]

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[Received for publication May 1, 1946]

The practice of Oriental gardeners of soaking narcissus and other bulbs in aged urine before planting suggested that the immersion of iris bulbs in urea solutions might reduce the losses that glasshouse operators sustain through bulb rots caused by *Penicillium* sp. and other bulb pathogens; and the report by Bawden and Pirie (1), which showed that urea will inactivate certain plant virus suspensions, suggested that a prolonged immersion of bulbs in a urea solution might destroy virus infection.

EXPERIMENTAL

For three years in succession, small lots of iris bulbs were immersed in a 1% solution of urea and forced under glass in the usual manner. The urea treatments, as shown by the data in Table 1, induced longer stems and earlier and more abundant bloom than occurred in the controls. The foliage that developed upon the urea-treated bulbs was also deeper green in colour. The healthy appearance of the foliage, bulbs, and fibrous roots of the controls indicated that the stimulation was not due to the control of parasitic fungi or to the destruction of virus infection. However, virus disease in the iris varieties Wedgewood and Supreme is wide-spread and diagnosis is not easy.

TABLE 1.—THE INFLUENCE OF THE IMMERSION OF 9 CM. IRIS BULBS IN 1% UREA ON EARLINESS AND ABUNDANCE OF BLOOM

Season, Immersion date, Variety	No. of bulbs	Immersion period	First bloom	Stem length	Quantity of bloom
				in.	%
1932–33, Sept. 11, Wedgewood	30	Urea 3 hrs.	Jan. 24	18.5	90
	30	Water 3 hrs.	Jan. 28	17.0	70
	30	Untreated	Jan. 29	16.5	78
1933–34, Oct. 28, Wedgewood	24	Urea 24 hrs.	Jan. 13	19.0	96
	24	Water 24 hrs.	Jan. 17	14.0	75
	24	Untreated	Jan. 18	15.0	66
1934–35, Oct. 12, Supreme	19	Urea 24 hrs.	Jan. 9	—	100
	19	Water 24 hrs.	Jan. 13	—	66
	19	Untreated	Jan. 13	—	55

Virus disease symptoms tend to disappear under favourable growing conditions, hence a quantity of bulbs was selected from plants that bore definite virus symptoms and these were immersed for twenty-four hours in a 1% urea solution. As illustrated by the data in Table 3, no evidence was obtained that the treatment destroyed the virus involved in iris mosaic.

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The inspection of the small scale laboratory trials led to the adoption of a twenty-four hour immersion in a 1% urea solution as an annual routine practice by local glass-house operators, and Brown Bros., Esquimalt, B.C., reported that they secured 85% bloom with urea-treated Wedgewood iris compared with 55% bloom in the controls. Although the forcing experiment of Brown Bros. was inspected and earlier bloom and growth stimulation through the urea treatment was apparent, the data are not included in Table 2. During the 1945–46 season, the Wooldridge Bulb Co., Saanichton, B.C., carried out a large scale experiment upon the influence of urea. Since the experiment was closely supervised, the data therefrom are given in Table 2.

TABLE 2.—THE INFLUENCE OF THE IMMERSION OF WEDGEWOOD IRIS BULBS IN 1% UREA ON EARLINESS AND ABUNDANCE OF BLOOM. A COMMERCIAL TRIAL

Season, Immersion date, Size	No. of bulbs	Immersion period	First bloom	Quantity of bloom
				%
1945–46,				
Aug. 7, 10 cm.	2428	Urea 24 hrs.	Dec. 21	80
	3150	Untreated	Dec. 28	72
Aug. 7, 9 cm.	2552	Urea 24 hrs.	Dec. 23	60
	2944	Untreated	Jan. 1	55

TABLE 3.—THE INFLUENCE OF THE IMMERSION OF 8 CM. MOSAIC INFECTED WEDGEWOOD BULBS IN 1% UREA FOR 24 HRS. ON BLOOM DEVELOPMENT AND VIRUS SYMPTOMS

Season, Immersion date	No. of bulbs	Immersion period	Bloom cut				Virotic plants
			Dec. 30	Jan. 5	Jan. 10	Jan. 13	
1941–42							
Aug. 20	50	Urea 24 hrs.	11	9	8	0	27*
Sept. 12	50	Urea 24 hrs.	2	9	6	3	30
Sept. 12	50	Water 24 hrs.	1	7	8	5	31

* Plants bearing unquestionable virus disease symptoms.

DISCUSSION

In all forcing trials with the varieties Wedgewood and Supreme, earlier and more abundant bloom was induced by immersing the bulbs in a 1% urea solution up to twenty-four hours. In all trials the healthy appearance of the fibrous roots, bulbs, and foliage of the treated and control plants after the bloom had developed indicated that the stimulation by urea was not due to the destruction of fungus pathogens or to the destruction of virus disease. In the 1941–42 trials with small lots of bulbs known to be infected with iris mosaic, the symptoms of mosaic were more difficult to detect in the plants from urea-treated bulbs than in the controls, due to the induction of greater vigour by the urea, but the number of plants that bore definite mosaic symptoms were practically identical in the treated compared with the controls.

The practice of treating iris bulbs with urea has proved to be of considerable economic importance to local forcers, not only because the yield of bloom is increased, but also because the early bloom is often the most profitable. In the 1945–46 commercial scale trials, the urea-treated and the control bulbs were subsequently stored for three weeks at approximately 46° F., a treatment which in itself tends to induce earlier and more abundant bloom, but this cool storage treatment did not mask the influence of urea. No critical evidence was obtained upon the optimum period of immersion. Since both the three hour and the twenty-four hour period were beneficial, the local iris forcers have adopted an immersion period of from twelve to twenty-four hours, depending upon the weather. When the weather is warm a shorter period is adopted than when the weather is cool.

SUMMARY

Iris bulbs that had been immersed up to twenty-four hours in a 1% solution of urea produced longer flower stems, deeper green foliage, and earlier and more abundant bloom than untreated bulbs when the bulbs were forced in a normal fashion under glass. The urea immersion increased the vigour of mosaic infected bulbs and to a slight degree masked the disease symptoms, but the number of plants that bore definite mosaic symptoms were practically identical in the treated and in the controls. No evidence was found that the stimulation by urea was due to the destruction of fungus pathogens or to the destruction of virus disease.

THE GROWTH OF *SCLEROTINIA SCLEROTIORUM* AND *ALTERNARIA SOLANI* IN SIMPLE NUTRIENT SOLUTIONS[1]

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[Received for publication May 1, 1946]

The study of the growth of *Sclerotinia sclerotiorum* (Lib.) de Bary and *Alternaria Solani* (E. & M.) Jones & Grout in simple nutrient solutions was undertaken to establish a standard nutrient solution that contained only essential basic constituents. A simple mineral-dextrose solution was adopted as the starting point. It consisted of a mixture of potassium phosphate, potassium nitrate, and dextrose, for no measurable growth was obtained when the sugar or any of the constituent ions of these compounds were omitted. Throughout this investigation the introduction of traces of nutrients, through the inoculum and through impurities in the C.P. chemicals used, has been ignored.

EXPERIMENTAL

In this study, 25 ml. portions of the nutrient solutions in 250 ml. Erlenmyer flasks were each inoculated with a small portion of mycelium taken from the periphery of Petri dish agar cultures, and the flasks were incubated for 10 days at 25° C. After the completion of the incubation period, each mycelial mat was transferred to a beaker containing 100 ml. of distilled water and re-transferred after one hour from the water to a weighing dish in which the mat was dried to constant weight at 100° C.

The nutrient solutions employed, designated in a manner to indicate their composition, are as follows:

K . P . NO_3		K . P . Mg . S . NO_3		K . P . Mg . S . Ca . NH_4	
K_2HPO_4	0.2 g.	K_2HPO_4	0.2 g.	K_2HPO_4	0.2 g.
KNO_3	0.2 g.	KNO_3	0.2 g.	$(NH_4)_2HPO_4$	0.2 g.
Dextrose	20.0 g.	$MgSO_4$	0.1 g.	$MgSO_4$	0.1 g.
Water	1000.0 ml.	Dextrose	20.0 g.	$CaSO_47H_2O$	0.1 g.
		Water	1000.0 ml.	Destrose	20.0 g.
				Water	1000.0 ml.

K . P . Mg . NO_3		K . P . Mg . S . $CaNO_3$		K . P . Mg . S . Ca . Asparagin	
K_2HPO_4	0.2 g.	K_2HPO_4	0.2 g.	K_2HPO_4	0.2 g.
KNO_3	0.2 g.	KNO_3	0.2 g.	$MgSO_4$	0.1 g.
$MgHPO_4 . 7H_2O$	0.1 g.	$MgSO_4$	0.1 g.	$CaSO_4$	0.1 g.
Dextrose	20.0 g.	$Ca SO_4 . 7H_2O$	0.1 g.	Asparagin	0.2 g.
Water	1000.0 ml.	Dextrose	20.0 g.	Dextrose	20.0 g.
		Water	1000.0 ml.	Water	1000.0 ml.

The results are given in Table 1.

DISCUSSION

When *Sclerotinia sclerotiorum* and *Alternaria Solani* were grown in liquid media containing K_2HPO_4, KNO_3, and dextrose, the dry weight of the mycelia progressively increased with the successive addition of the

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TABLE 1.—WEIGHTS OF *Sclerotinia sclerotiorum* AND *Alternaria Solani* mats after 10 days growth at 25° C.

Media	*Sclerotinia sclerotiorum*			*Alternaria Solani*		
	No. of cultures	Mean wt. and error	Final pH	No. of cultures	Mean wt. and error	Final pH
		mgs.			mgs.	
K . P . NO_3	5	43 ±4.5	2.5 – 2.6	11	26 ±0.8	6.9 – 7.1
K . P . Mg . NO_3	5	54 ±4.0	2.5 – 2.6	6	35 ±1.3	6.9 – 7.2
K . P . Mg . S . NO_3	7	96 ±4.9	2.5 – 2.6	11	75 ±1.0	7.0 – 7.2
K . P . Mg . S . Ca . NO_3	8	131 ±7.7	2.5 – 2.7	11	83 ±3.2	6.8 – 7.0
K . P . Mg . S . Ca . NH_4	8	103 ±7.6	2.4 – 2.5	8	16 ±1.0	3.7 – 4.3
K . P . Mg . S . Ca Asparagin	8	73 ±5.7	2.7 – 2.8	9	70 ±3.3	6.4 – 6.8

Necessary difference for 5% of significance = 8.4.

ions Mg+, SO^4−, and Ca +, with the possible exception of Ca + in the *A. Solani* cultures where the difference was less than the 5% level of significance. The replacement of the NO_3− ion with NH_4+ had only a small inhibitory effect upon the growth of *S. sclerotiorum* but a very pronounced inhibitory effect upon the growth of *A. Solani.* The growth of *A. Solani* was less in the media containing all the mineral salts and the NH_4+ ion than in the mineral deficient media containing only K_2HPO_4 and KNO_3 in addition to dextrose. Unlike *S. sclerotiorum*, *A. Solani* either cannot utilize effectively the ammonium ion as a sole source of nitrogen or else the acid formed in the presence of the ammonium ion has a pronounced inhibitory effect. The final values of pH of all the *A. Solani* cultures were close to the neutral point, except in the cultures containing the ammonium salts, where the final values varied from pH 3.7 to pH 4.3. Neither fungi grew as well in the cultures containing asparagin as the sole source of nitrogen as in the corresponding complete nutrient cultures containing nitrate. Asparagin, however, proved to be a satisfactory source of nitrogen for both fungi.

SUMMARY

When *S. sclerotiorum* and *A. Solani* were grown in liquid media containing K_2HPO_4 and KNO_3 in addition to dextrose, the weights of the mycelia progressively increased with the successive additions of the ions Mg+, SO_4−, and Ca+. The replacement of NO_3− with NH_4+ had a marked inhibitory effect upon the growth of *A. Solani*, but inhibited only slightly the growth of *S. sclerotiorum.* Although inferior to nitrate, asparagin was a good source of nitrogen for both fungi.

THE LONGEVITY OF *PHOMA BETAE* IN GARDEN BEET SEED[1]

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[Received for publication May 1, 1946]

The longevity of *Phoma Betae* Frank in garden beet seed, variety Detroit Dark Red, was studied as part of an exploratory program of ways and means of preventing the introduction through seed of plant disease into newly established seed growing areas in British Columbia. The possibility existed that the longevity of certain plant pathogens in seed was shorter than the period that the host seed could be stored without effecting a serious reduction in germination.

EXPERIMENTAL

In this study of the longevity of *Phoma Betae* in garden beet seed, the sample of seed was stored in a cool dry cellar. The sample was grown in the Northern Okanagan district, and the 1940 comparative trials of B.C. Certified seed showed that a high percentage of the seed therein was infected with *Phoma Betae*. Each year one or more samples of 100 clusters were withdrawn and planted equally spaced in flats of autoclaved soil. Table 1 is a record of the percentage of the clusters in which one or more seeds germinated, the total number of seedlings that developed from each sample of 100 clusters, and the percentage of the seedlings that were killed through *Phoma Betae* infection.

TABLE 1.—THE LONGEVITY OF *Phoma Betae* IN GARDEN BEET SEED SAMPLES OF 100 CLUSTERS

Time of year	Planting month	Cluster germination	Number of seedlings	Seedling* death
		%		%
1940	Dec.	80	121	33
1941	May	82	132	23
1942	Mar.	79	132	23
	Mar.	89	128	24
1943	May	82	127	20
	May	81	126	21
	June	81	124	22
	June	80	127	19
1944	Feb.	84	134	4
1945	Jan.	93	169	4
	Oct.	92	156	3
	Dec.	94	158	2

* Based primarily on the 1943 replications, differences less than plus or minus 2 have little significance.

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DISCUSSION

Although the decrease with the age of the seed of seedling deaths through *Phoma Betae* infection is of interest, seed-borne infection is seldom if ever of sufficient economic importance to justify the establishment of a five-year seed-storage period as a control measure. The five-year seed-storage period had no adverse effect upon germination. The data in Table 1 suggest that the slight increase in germination strength after storing for five years may be significant, but as so many factors influence seed germination, the inference is not drawn that the slight increase in the germination strength is due to the decrease in the amount of *Phoma Betae* infection. The increase in germination would probably have escaped notice had not Mr. C. Tapp, Seed Analyst, Vancouver, B.C., discovered a similar case. Upon re-testing a five-year-old sample of well matured garden beet seed, he found the germination had improved.

Although the introduction of *Phoma Betae* into new seed-growing districts apparently cannot be prevented by using five-year-old seed, nevertheless, plant pathologists should not neglect the possibilities of preventing the introduction of disease by the simple expedient of using old seed. This may be illustrated by seed transmission studies of tomato streak, *Lycopersicum* virus 1. A 72% transmission was obtained when the seed and adhering pulp were planted immediately after the diseased fruits were harvested. After the seed was thoroughly freed from the pulp by shaking in a 2% sulphuric acid solution, the transmission value fell to 30%. When the acid cleaned seed was stored for one year, the transmission values varied from zero to 4%.

SUMMARY

Seedling death in garden beets, variety Detroit Dark Red, through *Phoma Betae*, decreased with the age of the seed from over 30% to less than 5% over a five-year seed-storage period, and over the same period there was no decline, but rather a slight increase in the germination.

GERMINATION OF WEED SEEDS

I. LONGEVITY, PERIODICITY OF GERMINATION, AND VITALITY OF SEEDS IN CULTIVATED SOIL[1]

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[Received for publication April 29, 1946]

The earth's surface is clothed with a cover of vegetation, except under conditions of continually frozen ground or extremely arid climate, or where man deliberately attempts to keep the land free from all forms of growth. Numerous natural and artificial agencies tend to suppress or destroy this vegetative cover, but plants continue to spring up from bare ground. During years of extreme drought and wind erosion, millions of acres of land in the arid and semi-arid regions of North America have been laid bare for many months at a time. Yet with one good rain and a relatively short period of fairly stable atmospheric conditions, plant growth reappeared over many of the stricken areas in sufficient amounts to give complete protection against subsequent damaging effects of high wind and heavy downpours of rain.

The ability of many plant species to reappear in areas denuded of vegetation is due principally to dormancy of seeds. Dormancy, or resting period, of seeds buried in the soil is particularly long in a great number of plant species, especially those depending on natural conditions for propagation. Hence, once land has become clothed with a natural cover of vegetation, it is virtually impossible for any agency to destroy it permanently, for many seeds that may shatter on the ground will remain in a dormant state for many years and the small proportion of them that germinate in any year may reach maturity and add more seeds to those already present in the soil. This characteristic behaviour, particularly of species not propagated by man, such as weeds, constitutes one of the major natural factors in soil conservation. Yet this very characteristic, essential as it may be for soil conservation, often brings serious difficulties for man on the land. Many weeds are serious pests by virtue of the fact that dormant seeds shatter in large numbers and keep springing up in cultivated crops. Competition for moisture and plant food is generally acute in highly infested fields and losses sustained in lowered quality and reduced yields of crops are often very great.

It should be pointed out that seeds of some weeds do not exhibit a marked dormancy and for this reason alone may be controlled or eradicated by methods that are different to those suitable for weeds whose seeds exhibit a high degree of dormancy in the soil. When plowed under, seeds of a low degree of dormancy will germinate, and if buried too deeply will rot away without emerging. Those exhibiting a high state of dormancy, on the other hand, will be preserved by burial and will germinate only after they are brought nearer to the surface.

[1] Contribution from the Experimental Farms Service (P.F.R.A.), Dominion Department of Agriculture, Ottawa, Canada.

[2] Agricultural Scientist.

A successful control of weeds necessitates the destruction of viable seeds. It is essential therefore to create such condition of the soil that would tend to stimulate germination of dormant seeds, which later may be destroyed by tillage. There is far too little information at the present time on the relative dormancy of seeds of different weeds and on the conditions that favour their germination. Such information is of great importance in relation to tillage practices. A knowledge of the causes of dormancy of weed seeds, their behaviour under various conditions in the soil, and the methods by which they could be most readily destroyed, will aid the scientist and the farmer in working out effective methods of eradication.

In order to answer some of the elementary questions connected with the nature and degree of dormancy of seeds of different weeds and the methods of cultivation that would facilitate their eradication, a series of experiments was undertaken at this laboratory in 1937, the results of one of which are reported herewith.

LITERATURE

There are many records of longevity of weed seeds in undisturbed soil. The two most extensive buried seed projects on which considerable data are available are those initiated by Beal (7) in 1879 and by Duvel (10) in 1902. These and other experiments (5) show that seeds of many weeds retain their vitality in undisturbed soil for 60 years or more. Hard seeds that do not absorb water were found to be especially adapted for long periods of vitality in moist soil. However, many of the weed seeds of long life span in soil are not hard and imbibe water freely, yet stored food in these seeds is not soon exhausted by respiration. Atwood (1) found that the initial rate of respiration of dormant imbibed seeds of *Avena fatua* is high at first but that the rate soon drops to a very low level, suggesting that curtailment of respiration must be enormous for seeds buried in moist soil. Crocker (5) concludes from comparative results of Ewart (8) and Beal (7) that the life span of some seeds buried in the soil is longer than in ordinary dry storage.

Although there are numerous records of the length of life of seeds in undisturbed soil, such as in sod, little information is available on length of life in cultivated soil. Of the very few such experiments, those of Brenchley and Warington (2, 3, 4) are outstanding. In these investigations a thorough analysis was made of the effect of different cultural and cropping methods on the weed seed population of the soil and on the nature and length of period of dormancy of seeds of many weeds. Brenchley and Warington (2) assert that dormancy is of two distinct types, "natural" and "induced". Natural dormancy is due to some physiological state of the seed that prevents germination, even in a favourable environment. Induced dormancy, on the other hand, is forced upon the seeds by some condition of the environment that is unfavourable for germination, such as the exclusion of oxygen supply resulting from deep burial in the soil. At low depths in the soil some seeds are able, by force of conditions, to retain their viability for many years.

The naturally dormant seeds will germinate as soon as they reach a physiological state that enables them to germinate, provided that environ-

mental conditions are suitable. A statement that seeds of certain species are able to stay dormant in the soil for some definite period, however, does not mean that all seeds in any given sample would behave in this manner. A certain proportion may exhibit no period of natural dormancy and will germinate as soon as they are subjected to favourable conditions. Others will follow in order, however, until all have germinated. The length of period required for all the seeds to reach a state that allows them to germinate has been designated as their natural period of dormancy (2).

For many weeds, the period of natural dormancy is believed to be much shorter than the period of induced dormancy. Hence seeds that are reputed to remain viable in undisturbed soil for 60 years or more, may, under suitable cropping and tillage practices, grow out of the soil in the course of a few years. This puts the weed control problem in new light, for weeds that were once believed impossible of eradication within the course of several decades might be destroyed with appropriate methods within much shorter periods. The general trend in agricultural practice in Western Canada is to work the land as shallow as is consistent with effective destruction of weed growth. Weed seeds under such procedure are not buried deeply and the majority are in a position to germinate as soon as they are physiologically ready for germination. Their longevity in shallow cultivated soil is therefore more comparable to the period of natural dormancy than to period of induced dormancy caused by the older and now more or less obsolete tillage practices.

Since little information is available on the periods of seed dormancy for different weeds in shallow cultivated soil, and since the knowledge of the behaviour of weed seeds in the soil is believed to be essential in working out effective methods of weed control, it was decided to undertake the study on this phase of the problem.

MATERIALS AND METHODS

Weed seeds chosen for investigation were taken at random from samples grown during the current year. Three sets of seeds, originating in 1937, 1938, and 1940, were chosen for the experiment. The seeds were mixed into a 2.5-inch layer of moist sterilized clay, loam, and sandy loam soil and were put into open bottom galvanized iron frames 12 inches square in the field about November 15.

The soil immediately below the layer containing the weed seeds was sterilized to the full depth of 6 inches. No seedlings appeared immediately after November 15 but records of seedlings emerging during the next and each succeeding year were made as soon as they appeared. The seedlings were identified, counted, and pulled out with the roots soon after emergence, but where doubt existed as to their identity they were left to grow until such time as they could be definitely identified. Care was taken that no soil sticking to the roots was thrown out and that no roots that might produce new shoots were left in the ground.

To avoid contamination, the area in the immediate vicinity of the trays was covered with a 3-inch layer of coarse gravel and this area was fenced in with fine chicken netting. A similar fence was placed some distance away and the ground between the fences and on the outside was sown per-

manently to grass. The trays were covered with tar paper from about November 15 to March 31 in order to avoid weed seeds being blown in with the snow. The ground was frozen and virtually no germination occurred during this period. Only one seedling out of a total of many thousands emerged early in November, hence all records of emergence cover periods only from April 1 to October 31.

In order to ascertain as to whether or not any weed seeds found their way in from the outside, 9 trays out of a total of 288 were filled with sterilized soil and seedlings that appeared in these trays were concluded to have been brought in from the outside. Seedlings of 4 species *Salsola Pestifer*, *Portulaca oleracea*, *Amaranthus retroflexus*, and *Monolepis Nuttalliana* grew in the blank trays but in such low numbers that they could not possibly interfere with the general results for these particular weeds.

The soils in the trays were kept in fallow one year and sown to spring wheat or barley in alternate years. The treatment of fallow consisted of turning the soil over with a trowel 2 or 3 times during the season and to the depth not exceeding 3 inches. This had to be done very carefully to avoid destroying the seedlings which might be in the soil but not emerged. The soils were worked once to a similar depth during the crop year, this being done just prior to seeding.

The tillage and cropping treatment described above was continued for 3 years with the 1937 seeds, for 6 years with the 1938 group, and is still being continued with the 1940 seeds. After field treatment, the soils of the first two groups were washed through an 80-mesh sieve, which was fine enough to prevent the loss of even the smallest seeds. The residue, along with the seeds that survived the field treatment, was placed in shallow saucers in a layer not exceeding 1 inch in depth and subjected to repeated germination tests in the laboratory with occasional stirring until no more seeds would germinate. It was concluded, if seedlings failed to appear for a period of 2 consecutive years, that all viable seeds had germinated. The length of time required for all seeds to germinate varied from a few weeks to many years, depending on the species. Except for hard seeds, however, most of the seeds germinated within 3 years.

Each species favoured a particular temperature and moisture condition for germination. *Salsola Pestifer* germinated in large numbers under a temperature of about 40° F. and under a relatively low soil moisture content. *Portulaca* and most members of the *Amaranthaceae* family, on the other hand, required periods of high temperature and relatively low soil moisture content before they would germinate. The samples under experiment were subjected to germination under variable temperature and moisture conditions in order to effect the possible maximum germination of all weeds in the shortest possible time. The samples were frozen on several occasions.

RESULTS

The numbers of seedlings emerging in each tray in the field have been grouped in semi-monthly periods in order that some estimate may be made of the exact length of dormancy of the seeds of each species and of the effect of season on germination.

It is seen that some seeds germinated immediately after they were placed under suitable conditions in the field, indicating that they were physiologically ready for germination and all that was required was to place them in a favourable environment. A certain proportion of the remaining seeds, however, kept on emerging out of dormancy and germinating until all had grown out of the soil. The period required for all seeds to germinate is designated as the maximum period of dormancy. The rate of emergence from dormancy, and hence the frequency of germination, varied greatly, depending upon the characteristic habit of the species. In some, the maximum period of dormancy was only a matter of a few months, in others many years.

In addition to the differences in the maximum period of dormancy there were also differences in the relative frequency of emergence from dormancy within the life span of all the seeds. Species differed greatly in this respect, some showing relatively few seeds emerging out of dormancy and germinating during the first year, followed by a fair proportion germinating each year thereafter until all had germinated. Other species, even with the same maximum life span of seeds, showed a relatively high emergence during the first year followed by relatively few emerging throughout subsequent years.

This variation in germination has a very important bearing on the practical aspect of weed control. It is evident that longevity, or length of dormancy, for the two cases cited above would be either the same or widely different, depending on the viewpoint that is to be adopted. If longevity is to mean the length of period required for all the seeds to grow out of or lose their viability in the soil, then it would be identical in the two cases cited. If, on the other hand, longevity, or length of dormancy, is to mean the *average* life span of all the seeds of a given sample, then it would be much greater in the former than the latter case.

From the point of view of weed eradication, consideration of the maximum period of dormancy would seem to be of paramount importance, but from the standpoint of weed control information on the average period of dormancy would be at least equally important. From what follows, it will be shown that many species produce a relatively large proportion of seeds that lie dormant, even under the most favourable environment for germination, for periods longer than the duration of any practical farm program that might be undertaken to rid the soil of weed seeds. There is, therefore, little hope of ever being able to rid the land of some weeds and the general farm practice that is to be adopted must be of such a nature as to enable the farmer to attain the maximum possible control of these weeds.

The average period of dormancy of seeds of different weeds was determined by summing the products of the number of months between the seeding of weed seeds and their germination and the percentage of germination within each particular month. For seeds of exceedingly long period of dormancy, however, the average period of dormancy could not be determined from the results so far obtained and these species were therefore classified on the basis of their relative length of seed dormancy. The relative length of seed dormancy was determined by summing the products

TABLE 1.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Maximum tillage depth 3″; no seeds were put below this depth; an indefinite number of seeds was sown on Sept. 18, 1937, but subsequent pollution of the soil was prevented)

Weed	Clay				Loam				Sandy loam			
	Emerged in the field			Viable seeds left*	Emerged in the field			Viable seeds left*	Emerged in the field			Viable seeds left*
	1938 (fallow)	1939 (wheat)	1940 (fallow)		1938 (fallow)	1939 (wheat)	1940 (fallow)		1938 (fallow)	1939 (wheat)	1940 (fallow)	
	%	%	%	%	%	%	%	%	%	%	%	%
Bromus tectorum	100.0	0	0	0	100.0	0	0	0	100.0	0	0	0
Agropyron repens	82.8	3.4	10.3	3.5	76.3	0	2.6	21.1	73.6	2.9	8.8	14.7
Setaria viridis	99.2	0.8	0	0	100.0	0	0	0	100.0	0	0	0
Bilderdykia Convolvulus	98.5	1.5	0	0	98.9	0	1.1	0	96.8	3.2	0	0
Chenopodium album	47.4	1.5	8.8	42.3	44.6	9.5	27.2	18.7	44.9	2.1	32.9	20.1
Axyris amaranthoides	65.0	7.0	15.9	12.1	69.8	24.0	3.1	3.1	36.0	13.8	16.9	33.3
Salsola pestifer	98.4	1.3	0	0.3	100.0	0	0	0	99.5	0.5	0	0
Amaranthus retroflexus	53.8	2.0	4.2	40.0	30.3	0.4	13.7	55.6	71.1	0.4	12.1	16.4
Amaranthus blithoides	79.5	1.0	0	19.5	89.3	0.5	1.3	8.9	87.3	3.0	0.8	8.9
Amaranthus graecizans	20.4	1.2	4.2	74.2	19.6	2.8	11.9	66.4	27.5	0	0.2	72.3
Portulaca oleracea	19.8	1.4	8.9	69.9	18.1	2.3	32.3	47.3	48.9	3.8	19.1	28.2
Baccaria vulgaris	100.0	0	0	0	99.4	0.6	0	0	100.0	0	0	0
Lepidium perfoliatum	7.0	0.5	6.4	86.1	22.6	0.5	5.3	71.6	19.5	0	18.9	61.6
Lepidium densiflorum	4.3	0.7	4.6	90.4	34.2	1.5	10.5	53.8	8.2	0.4	13.5	77.9
Thlaspi arvense	77.0	10.7	3.6	8.7	94.3	4.4	0.5	0.8	98.1	1.4	0	0.5
Sisymbrium altissimum	63.0	0.2	18.4	18.4	65.2	0.6	17.9	16.3	37.9	0	23.2	38.9
Sophia multifida	29.0	3.2	19.4	48.4	74.4	0	12.8	12.8	44.0	0	8.5	47.5
Conringia orientalis	100.0	0	0	0	100.0	0	0	0	98.0	2.0	0	0
Sinapis arvensis	93.6	1.5	3.4	1.5	97.7	1.7	0.6	0	99.0	0	0.5	0.5
Brassica juncea	99.4	0.6	0	0	100.0	0	0	0	100.0	0	0	0
Convolvulus americanus	5.0	1.0	7.1	86.9†	3.2	0.0	4.3	92.5†	5.5	3.3	4.4	86.8†
Lappula echinata	69.7	0	30.3	0	84.6	0	7.7	7.7	84.5	4.4	2.2	8.9
Solanum triflorum	93.5	5.9	0.6	0	90.1	9.5	0.4	0	98.2	1.6	0.2	0
Plantago major	9.6	1.2	2.4	86.8	11.7	3.4	17.2	67.7	11.2	3.0	6.4	79.4
Helianthus aridus	91.2	2.6	1.4	4.8	90.1	6.6	0.7	2.6	93.2	3.9	0.8	2.1
Lactuca virosa	44.6	8.9	16.6	29.9	38.8	6.1	31.6	23.5	50.5	1.9	28.6	19.0
Sonchus arvensis	43.3	16.2	2.7	37.8	66.7	13.3	0	20.0	86.7	0	3.3	10.0

* The number of viable seeds remaining in the soil at the end of 3 years of exposure in the field was determined by repeated germination tests in shallow trays in the laboratory until no more germinate.

† Hard seeds germinated after immersion in concentrated sulphuric acid for 24 hrs. Other species did not contain hard seeds.

TABLE 2.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Tillage 3″ deep, no seeds being placed below this depth; seeds were sown on October 14, 1938)

Weed	No. of seeds sown in the field	Numbers germinated. *†	Clay							Loam							Sandy loam						
			Numbers emerged in the field						*	Numbers emerged in the field						*	Numbers emerged in the field						*
			1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	Viable seeds left	1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	Viable seeds left	1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	Viable seeds left
Bromus tectorum	100	—	18	13	0	0	0	0	0	46	12	1	0	0	0	0	24	9	0	0	0	0	0
Agropyron repens	50	—	28	2	1	0	0	0	0	5	3	0	0	0	0	0	23	0	2	0	1	0	0
Avena fatua	100	—	50	19	3	0	0	0	0	39	13	1	0	0	0	0	28	11	0	1	0	0	0
Setaria viridis	300	33	13	0	0	0	0	0	0	11	1	0	0	0	0	0	18	0	0	0	0	0	0
Bilderdykia Convolvulus	100	64	69	0	0	0	0	0	0	47	3	3	0	0	0	0	67	4	0	0	0	0	0
Corispermum marginale	300	—	29	1	6	2	1	0	0	17	12	33	55	5	7	17	41	9	26	6	0	1	1
Chenopodium album	300	126	57	16	22	17	2	6	58	44	14	5	12	0	6	42	44	13	14	36	1	2	22
Asygris amaranthoides	300	135	100	8	6	5	1	1	21	58	18	8	1	0	0	70	85	6	11	8	1	1	43
Salsola pestifer	100	—	68	0	0	0	0	0	0	30	0	0	0	0	0	0	82	0	0	0	0	0	0
Amaranthus retroflexus	300	249	39	19	24	32	0	9	97	43	6	34	21	2	6	50	65	12	28	36	1	15	63
Amaranthus blithoides	300	207	78	0	15	44	2	9	80	40	0	47	52	0	11	54	45	7	46	89	0	21	42
Amaranthus graecizans	300	159	35	1	12	27	0	1	89	76	0	5	28	0	8	59	47	0	20	43	1	14	40
Portulaca oleracea	300	189	2	0	19	0	0	1	99	2	13	15	0	0	4	45	5	4	5	0	0	2	78
Vaccaria vulgaris	100	100	50	0	0	0	0	0	0	24	0	0	0	0	0	0	44	0	0	0	0	0	0
Lepidium perfoliatum	300	168	6	1	11	8	1	2	81	15	5	3	3	8	7	62	35	2	17	8	1	14	49
Lepidium densiflorum	300	—	7	7	4	8	0	8	49	13	3	11	5	2	9	25	36	5	17	7	0	7	30
Thlaspi arvense	300	177	93	44	41	78	1	3	0	58	19	11	6	0	0	0	137	17	18	7	0	0	0
Sisymbrium altissimum	300	201	53	0	4	5	1	1	6	22	16	15	26	6	14	6	71	1	26	12	0	20	9
Sophia multifada	300	165	6	4	7	4	0	0	65	9	14	6	10	4	4	26	15	20	18	7	1	4	29
Conbringia orientalis	300	210	158	1	0	0	0	0	0	32	1	0	0	0	0	0	105	0	0	0	0	0	0
Sinapis arvensis	300	189	123	11	11	19	0	6	8	54	8	15	14	0	3	5	117	19	7	2	0	0	0
Brassica juncea	300	300	97	0	0	0	0	0	0	10	0	0	0	0	0	0	104	0	0	0	0	0	0
Convolvulus americanus	50	—	2	1	1	1	1	2	10	0	5	1	0	0	0	8	1	4	0	2	0	0	8
Lappula echinata	300	264	111	3	0	0	0	0	0	25	0	2	0	0	3	0	130	2	0	0	1	0	0
Salanum triflorum	100	—	55	18	10	1	2	0	1	42	1	3	0	0	0	0	67	6	2	0	0	0	0
Cyclachaena xanthifolia	300	—	27	9	9	11	13	13	0	9	5	25	14	2	3	0	23	48	5	3	0	5	2
Helianthus aridus	100	44	60	0	0	3	0	0	0	20	1	0	0	0	0	0	40	1	1	0	0	0	1
Tragopogon dubius	30	—	23	0	0	0	0	0	0	2	0	0	0	0	0	0	8	0	0	0	0	0	0
Lactuca virosa	100	—	11	4	0	0	0	0	1	3	1	0	0	0	0	3	1	2	0	1	0	0	0
Sonchus arvensis	50	—	33	0	4	0	0	0	0	1	0	0	0	0	0	0	2	3	0	0	0	0	1

† Determined on another sample of the same seed from numbers germinating in 1 cm. layer of moist sand in the laboratory.
* As determined by repeated germination tests in shallow trays in the laboratory up to Jan. 21, 1946. Additional seeds of some species are expected to emerge after this date.

TABLE 3.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Tillage 3″ deep, no seeds being placed below this depth; seeds were sown between November 1 and 5, 1940.)

Weed	No. of seeds sown in the field	No. of viable seeds*	Clay: Numbers emerged in the field					Loam: Numbers emerged in the field					Sandy loam: Numbers emerged in the field				
			1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow
Bromus tectorum	1000	900	297	4	0	0	0	125	0	1	0	0	109	0	0	0	0
Agropyron repens	1000	390	322	0	1	0	0	456	0	0	0	0	396	1	0	0	0
Lolium rigidum	1000	620	484	28	0	0	0	393	14	1	0	0	347	10	0	0	0
Hordeum jubatum	1000	510	373	3	12	0	0	443	2	11	0	0	604	4	10	0	0
Avena fatua	1000	400	298	75	18	1	0	178	21	3	0	0	200	42	12	0	0
Setaria viridis	1000	760	562	3	8	0	1	531	0	0	0	0	468	0	0	0	0
Rumex mexicanus	1000	120	49	0	1	0	0	40	0	0	0	0	12	0	0	0	0
Polygonum neglectum	1000	310	275	44	10	4	0	168	7	1	2	2	166	15	0	2	0
Bilderdykia Convolvulus	1000	500	586	20	1	0	0	338	7	0	0	1	310	3	0	0	0
Chenopodium album	1000	550	24	4	43	27	4	18	7	10	16	6	6	7	6	20	11
Monolepis Nuttaliana	1000	760	33	1	10	13	12	42	1	5	5	16	36	1	10	31	19
Kochia trichophylla	1000	720	193	0	0	0	0	116	0	0	0	0	59	0	0	0	0
Corispermum marginale	1000	430	77	22	14	3	0	149	22	100	19	6	131	4	18	4	0
Atriplex hortensis	1000	870	567	5	9	0	0	487	22	25	5	2	230	6	4	0	2
Atriplex hastata	1000	490	331	2	26	19	0	319	12	2	5	2	344	46	11	17	2
Axyris amaranthoides	1000	590	221	39	31	32	10	118	37	15	28	2	80	36	21	14	3
Salsola Pestifer	1000	500	436	0	2	0	0	189	0	0	0	0	178	0	0	0	0
Amaranthus retroflexus	1000	710	276	1	11	27	4	147	1	8	9	6	148	0	9	20	5
Amaranthus blithoides	1000	370	265	4	22	47	20	222	28	11	32	14	212	41	22	33	10
Amaranthus graecizans	1000	340	174	1	0	39	7	121	4	15	31	5	135	0	21	14	1
Portulaca oleracea	1000	440	18	1	3	8	0	41	0	6	14	10	48	4	0	4	1
Spergula arvensis	1000	1000	72	0	27	10	2	68	16	13	10	2	99	13	28	18	3
Agrostemma githago	500	475	366	0	0	0	0	118	0	0	0	0	108	0	0	0	0
Silene noctiflora	1000	1000	265	5	141	23	3	201	4	53	30	3	216	12	122	20	16
Silene vulgaris	1000	950	197	8	34	28	9	197	2	11	9	6	132	2	9	8	0
Vaccaria vulgaris	1000	920	564	14	1	0	0	550	0	0	0	0	313	1	0	0	0
Lepidium perfoliatum	1000	670	55	1	18	7	25	81	0	24	10	14	44	0	8	6	3
Lepidium densiflorum	1000	1000	84	47	8	25	2	84	8	22	21	0	88	7	13	21	0
Thlaspi arvense	1000	970	266	115	45	11	1	187	35	23	1	0	300	47	99	3	0

TABLE 3.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL—*Concluded*

(Tillage 3″ deep, no seeds being placed below this depth; seeds were sown between November 1 and 5, 1940.)—*Concluded*

Weed	No. of seeds sown in the field	No. of viable seeds*	Clay: Numbers emerged in the field					Loam: Numbers emerged in the field					Sandy loam: Numbers emerged in the field				
			1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow
Capsella Bursa-pastoris	1000	200	4	0	8	0	0	29	13	13	17	1	27	10	23	13	0
Camelina sativa	1000	960	450	0	0	0	0	424	0	0	0	0	318	0	0	0	0
Camelina dentata	1000	1000	487	0	0	0	0	708	0	0	0	0	631	0	0	0	0
Camelina microcarpa	1000	880	156	0	0	0	0	584	0	0	0	0	629	0	0	0	0
Sisymbrium altissimum	1000	970	78	0	6	1	0	81	0	7	3	1	13	1	2	0	0
Sophia multifada	1000	600	6	19	23	11	3	77	7	13	17	7	63	11	31	11	9
Conringia orientalis	1000	610	535	3	0	0	0	249	0	0	0	0	204	0	0	0	0
Cheirinia cheiranthoides	1000	350	61	7	19	21	3	48	3	15	18	5	53	2	28	12	1
Sinapis arvensis	1000	700	339	15	55	18	5	187	13	26	2	2	187	8	51	7	3
Erucastrum gallicum	1000	310	131	3	22	2	2	112	0	7	0	1	144	0	0	0	0
Brassica juncea	1000	990	345	0	7	2	0	154	0	0	0	0	52	0	0	0	0
Peritoma serrulatum	700	586	396	76	0	9	1	241	107	3	13	2	257	30	0	3	0
Medicago lupulina	1000	460	15	154	29	43	7	22	116	12	32	4	6	131	12	25	4
Oenothera strigosa	1000	430	13	8	2	26	0	74	8	11	19	3	102	19	4	30	0
Asclepias speciosa	1000	230	104	6	0	0	0	86	2	0	0	0	43	2	0	0	0
Convolvulus americanus	1000	570	24	1	2	3	7	8	1	3	4	13	8	1	1	5	10
Lappula echinata	1000	820	214	1	2	4	0	107	1	1	0	0	85	1	0	0	1
Plantago major	1000	380	106	0	0	0	3	22	2	0	16	1	17	0	0	22	8
Cyclachaena xanthifolia	1000	280	51	20	1	13	0	1	0	0	0	0	19	5	4	5	0
Xanthium echinatum	1000	280	163	48	1	8	3	162	56	4	5	1	100	70	0	0	0
Grindelia perennis	1000	530	14	23	12	13	0	29	33	18	27	2	6	21	1	6	2
Helianthus aridus	1000	340	363	75	19	26	3	36	21	2	0	0	82	14	0	1	0
Cirsium arvense	1000	40	27	1	0	0	0	21	0	0	0	0	8	2	0	0	0
Tragopogon dubius	250	230	71	0	0	0	0	53	0	0	0	0	20	0	0	0	0
Taraxacum officinale	1000	230	5	3	2	6	0	48	8	3	2	0	45	3	1	3	0
Lactuca Scariola	1000	150	112	3	7	7	0	27	5	1	1	1	35	2	0	2	1
Lactuca virosa	1000	160	126	4	0	0	0	22	4	0	0	0	22	12	0	0	0
Sonchus arvensis	1000	240	18	0	2	5	0	16	0	0	0	0	12	0	0	1	0

* Determined on another sample of the same seed from percentage of seeds germinating in 1 cm. layer of moist sand in the laboratory. The tests were continued from Nov. 6, 1940, to Nov. 15, 1945, towards the end of which period no more seeds except those of *Silene noctiflora*, *Medicago lupulina*, *Convolvulus americanus* and *Plantago majo* would germinate. Seeds of these four were treated with concentrated sulphuric acid, after which treatment the viable seeds germinated immediately.

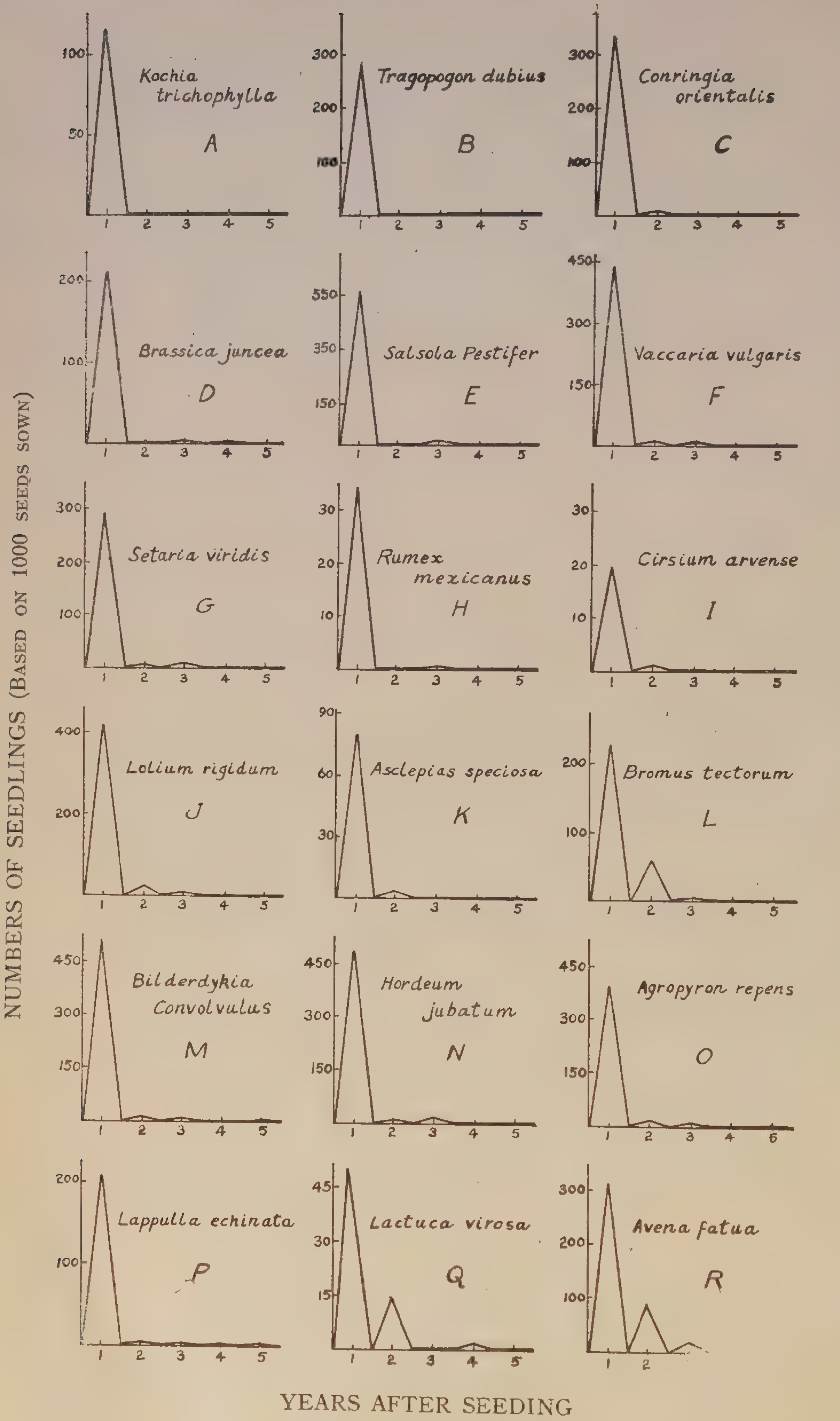

FIGURE 1. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

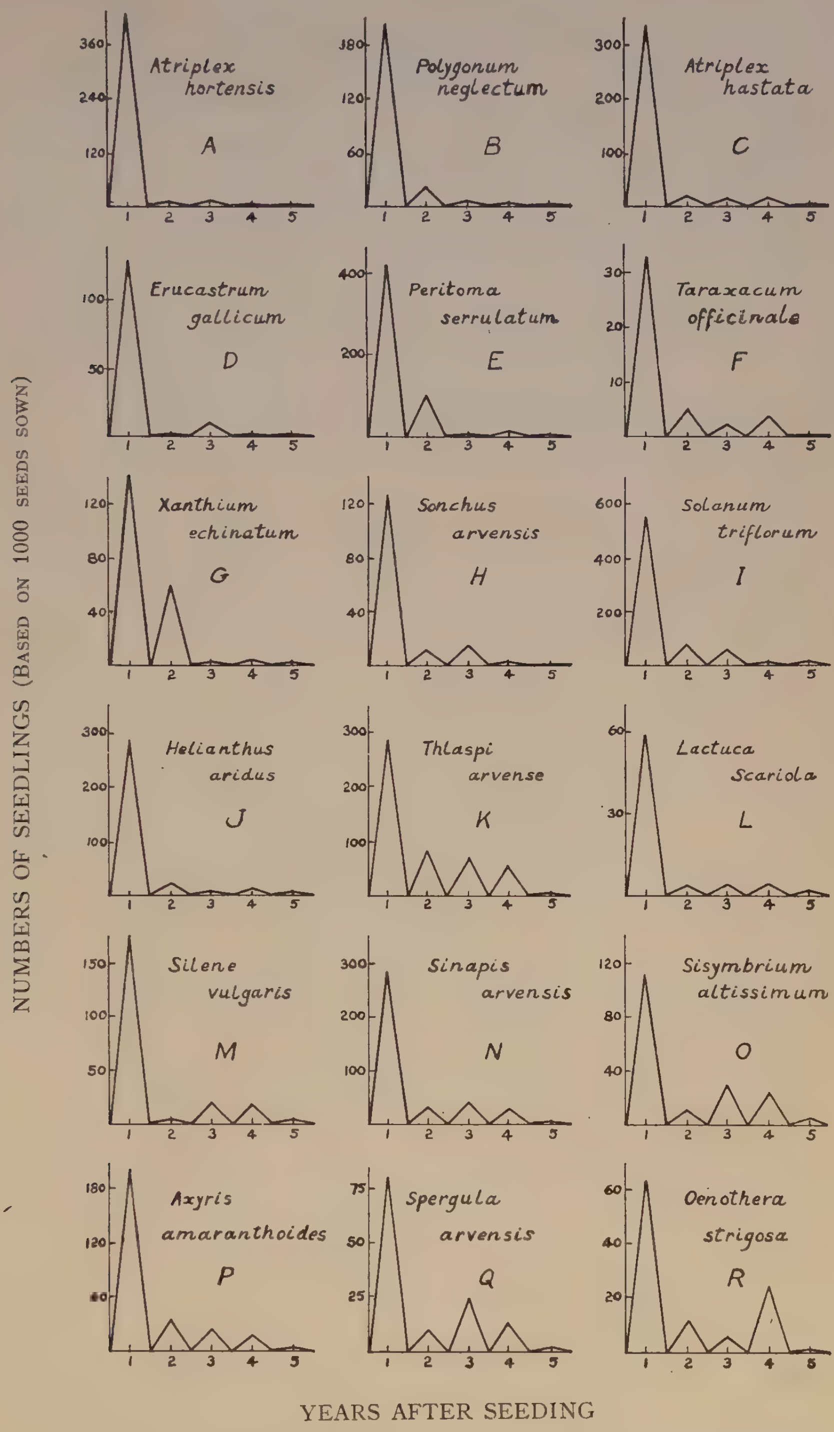

FIGURE 2. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

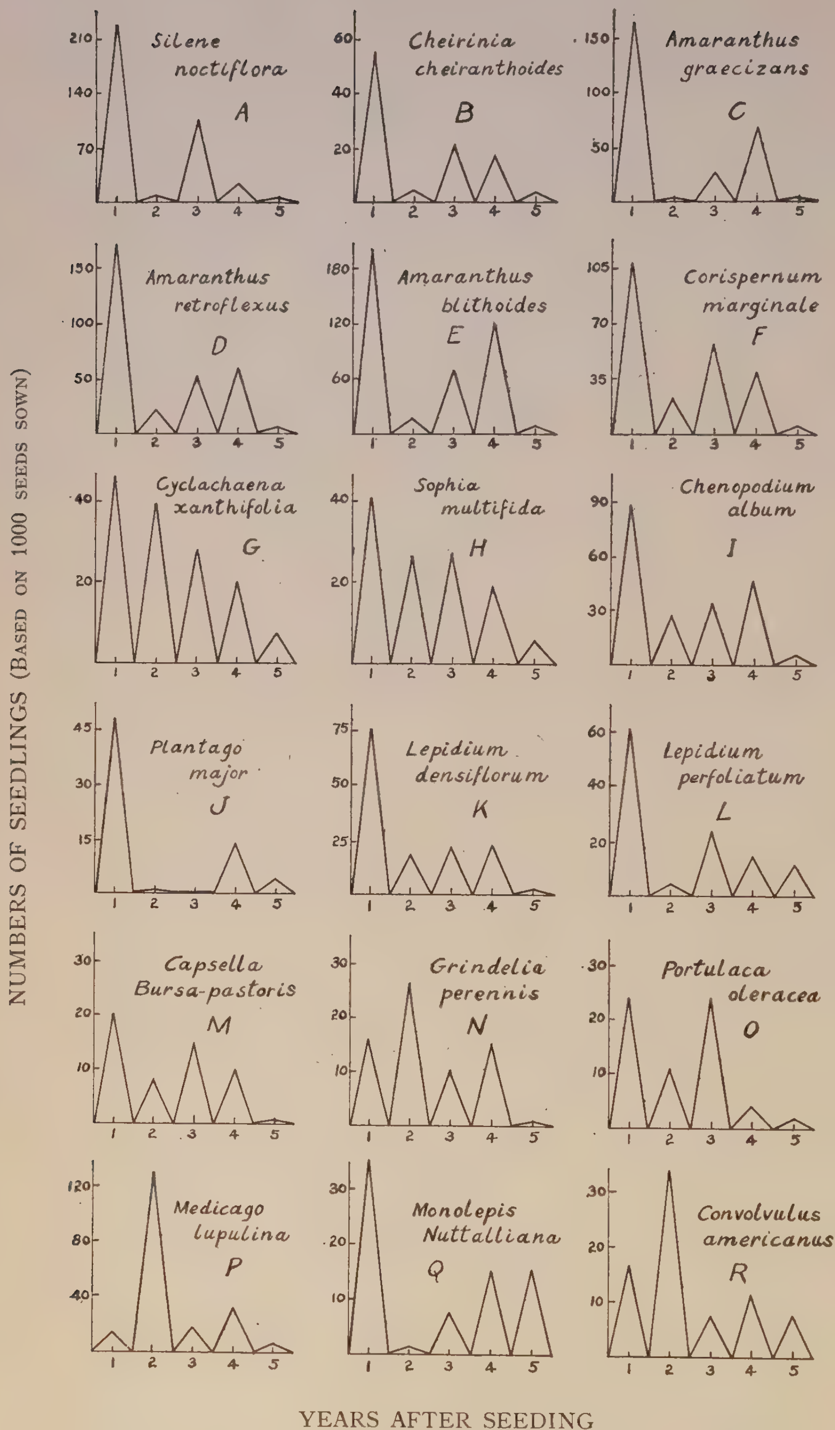

FIGURE 3. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

of the number of months between seeding and emergence and percentage of monthly germination. The monthly percentage was based on the total numbers germinating during a 5-year period. The average and the relative length of dormancy are determined in essentially the same manner and are therefore comparable.

The results of the experiment with the 1937 seeds are presented in Table 1. These results may be considered complete for all practical purposes. The data indicate the percentage of seeds, for each species, germinating during a 3-year period in the field and, as determined by laboratory tests already described, the percentage of seeds surviving the treatment in the field. As the number of species included in Table 1 was limited to 27, Tables 2 and 3, based on results for a more extensive number of species, are also presented. The data in Tables 2 and 3 are not fully completed, however, and samples are being kept under observation in order to follow the course of events still further. Because these latter experiments have not yet been completed, it is impossible at the present time to deal with the germination figures on a percentage basis, as in Table 1, and the results obtained to date are recorded merely by numbers of seeds germinating during each of the years the experiment has been conducted.

The data indicate the trend of results with respect to dormancy, but Figures 1, 2 and 3, based on the average results from Tables 2 and 3, have been prepared to show the trends more clearly.

It is evident that dormancy of weed seeds varies, depending on the year of origination. Hence the results given in this paper are exact only insofar as the behaviour of the particular samples of seeds chosen for experiment are concerned. Further experiments might change the average results, but judging from the results obtained on species common to each of the 3 sets of experiments, the variations are not particularly great in the majority of cases. Nevertheless, these experiments do indicate that the period of dormancy, as determined for seed of a given species maturing in any one year, cannot be assumed to be common to that particular species, and that in some cases these individual results might be at wide variance with the average.

On the whole, there were little, if any, differences in the average length of dormancy of seeds incorporated into clay, loam, or sandy loam soil.

The data indicate that while seeds of some species lie dormant in cultivated soil for only a very short time, many species contain a certain proportion of seeds that remain dormant in the soil for many years. The proportion of such seeds varies widely between different species and, in fact, no two species were found to be identical in this respect. Therefore, it was impossible to group them into distinct categories with respect to dormancy, but it was possible to list them according to the scale of shortest to longest average length of dormancy determined by the method already described. The maximum length of dormancy is also indicated in a general way.

LENGTH OF DORMANCY OF WEED SEEDS IN CULTIVATED SOIL:

(Listed in approximate order from shortest to longest average length of dormancy)

None to very short (maximum length of dormancy not exceeding 1 year):

1.	*Agrostemma githago*	Purple cockle, corn cockle
2.	*Camelina microcarpa*	Small seeded false flax
3.	*Camelina sativa*	False flax
4.	*Camelina dentata*	Round seeded or flat seeded false flax
5.	*Kochia trichophylla*	Kochia
6.	*Tragopogon dubius*	Yellow-goat's beard

Short to intermediate (maximum length of dormancy from 1 to 3 years):

7.	*Conringia orientalis*	Hare's ear mustard
8.	*Brassica juncea*	Indian mustard
9.	*Salsola Pestifer*	Russian thistle
10.	*Vaccaria vulgaris*	Cow cockle
11.	*Setaria viridis*	Green foxtail
12.	*Rumex mexicanus*	Willow-leaved dock
13.	*Cirsium arvense*	Canada thistle
14.	*Lolium rigidum*	Darnel
15.	*Asclepias speciosa*	Milkweed
16.	*Bromus tectorum*	Downy brome
17.	*Bilderdykia Convolvulus*	Wild Buckwheat
18.	*Hordeum jubatum*	Wild barley

Long to very long (maximum length of dormancy exceeding 3 years):

19.	*Agropyron repens*	Couch grass, quack grass
20.	*Lappula echinata*	Blue bur
21.	*Lactuca virosa*	Dentate prickly lettuce
22.	*Avena fatua*	Wild oats
23.	*Atriplex hortensis*	Garden atriplex
24.	*Polygonum neglectum*	Knotweed
25.	*Atriplex hastata*	Hastata atriplex
26.	*Erucastrum gallicum*	Dog mustard
27.	*Peritoma serrulatum*	Indian pink
28.	*Taraxacum officinale*	Dandelion
29.	*Xanthium echina um*	Cocklebur
30.	*Sonchus arvensis*	Perennial sow thistle
31.	*Solanum triflorum*	Wild mustard
32.	*Helianthus aridus*	Wild sunflower
33.	*Thlaspi arvense*	Stinkweed
34.	*Lactuca Scariola*	Lobed prickly lettuce
35.	*Silene vulgaris*	Bladder campion
36.	*Sinapis arvensis*	Wild mustard
37.	*Sisymbrium altissimum*	Tumbling mustard
38.	*Axyris amaranthoides*	Russian pigweed
39.	*Spergula arvensis*	Corn spurry
40.	*Oenothera strigosa*	Evening primrose
41.	*Silene noctiflora*	Night flowering catchfly

42. *Cheirinia cheiranthoides*	Wormseed mustard
43. *Amaranthus graecizans*	Tumbleweed
44. *Amaranthus retroflexus*	Red-root pigweed
45. *Amaranthus blithoides*	Prostrate amaranth, prostrate pigweed
46. *Corispermum marginale*	Bugseed
47. *Cyclachaena xanthifolia*	False ragweed
48. *Sophia multifida*	Flixweed
49. *Chenopodium album*	Lamb's quarters
50. *Plantago major*	Broad-leaved plantain
51. *Lepidium densiflorum*	Peppergrass
52. *Lepidium perfoliatum*	Perfoliate peppergrass
53. *Capsella Bursa-pastoris*	Shepherd's purse
54. *Grindelia perennis*	Gumweed
55. *Portulaca oleracea*	Purslane
56. *Medicago lupulina*	Black medic
57. *Monolepis Nuttalliana*	Spear-leaf goosefoot
58. *Convolvulus americanus*	Wild morning glory

Out of a total of 58 species, 6 had seeds whose life span in cultivated soil did not exceed one year and 18 had seeds that remained dormant in cultivated soil for periods not exceeding 3 years, except that a few of these had one or two seeds live past this period. None of these weeds, with the possible exception of *Salsola Pestifer* and *Cirsium arvense*, are particularly serious weeds, evidently because of their short longevity in cultivated soil. *Salsola Pestifer* is a serious weed in dry areas for reasons which will be pointed out later, whereas the seriousness of *Cirsium arvense* is due mainly to its persistent perennial habit of growth.

A number of species, in the neighbourhood of 22 to 28, depending on where the borderline cases are to be included, contained relatively few seeds that remained dormant in shallow depths in cultivated soil beyond a period of 3 years, and it is evident that these species could be controlled by suitable tillage practices. Approximately 30 of the species are shown to possess a particularly long period of dormancy in cultivated soil. Most of these latter species, wherever present in substantial numbers, constitute a very serious agricultural problem and for some of these no practical method is known at present that would effect their complete eradication.

It is seen from Table 4 that with most species there is a definite fluctuation in frequency of germination which tends to rise and fall in corresponding seasons throughout the whole life of the seeds. Table 4 has been prepared from average results obtained during 3 years after the initiation of each of the 3 series of experiments. The results of subsequent years are omitted in order to avoid a great amount of superficial detail, but it should be pointed out that the behaviour of the seeds following the 3-year period remained essentially the same.

The period of maximum or peak germination varied with the species and there was not a single period of the growing season when seeds of some species did not show a substantial emergence in the field. For the majority of the species studied, however, the peak of germination occurred within a relatively short period of about 3 weeks commencing about April 23,

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Bromus tectorum	1	0	489	179	84	9	4	3	5	1	3	50	7	8
	2	0	7	17	1	3	1	1	1	0	0	0	0	7
	3	0	1	0	1	0	0	0	0	0	0	0	0	0
Agropyron repens	1	0	280	800	172	34	15	11	12	3	3	2	4	1
	2	0	1	0	4	1	0	0	0	0	0	0	0	2
	3	0	0	5	2	0	1	0	0	1	0	0	0	3
Lolium rigidum	1	0	314	871	26	2	0	5	1	0	0	3	1	1
	2	0	32	18	1	1	0	0	0	0	0	0	0	0
	3	0	0	0	1	0	0	0	0	0	0	0	0	0
Hordeum jubatum	1	0	524	732	44	41	5	2	16	5	6	39	2	4
	2	0	4	1	1	0	0	0	0	0	0	3	0	0
	3	0	4	0	20	0	3	0	1	0	0	0	0	5
Avena fatua	1	0	105	455	52	27	5	104	31	1	3	16	0	0
	2	0	19	111	24	8	0	5	3	0	0	7	0	4
	3	0	0	0	20	0	5	0	0	0	0	0	0	8
Setaria viridis	1	0	0	1201	421	461	30	131	4	2	2	0	0	0
	2	0	0	0	0	2	3	1	0	0	0	0	0	0
	3	0	0	0	0	0	3	0	5	0	0	0	0	0
Rumex mexicanus	1	0	0	63	20	10	0	0	2	5	0	0	1	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	1	0	0	0	0	0	0	0	0
Polygonum neglectum	1	0	562	46	1	0	0	0	0	0	0	0	0	0
	2	0	64	1	1	0	0	0	0	0	0	0	0	0
	3	0	0	0	8	0	3	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Bilderdykia Convolvulus	1	0	851	661	315	8	2	7	5	0	0	0	0	0
	2	0	28	6	8	0	2	0	0	0	0	0	0	1
	3	0	0	1	1	3	0	0	0	0	0	0	0	0
Chenopodium album	1	0	441	21	370	11	9	6	1	0	0	0	1	0
	2	0	32	54	29	4	3	2	1	0	0	0	0	0
	3	0	64	191	58	26	39	17	0	3	1	0	0	0
Monolepis Nuttalliana	1	0	59	6	0	0	1	14	2	4	3	22	0	0
	2	0	1	0	2	6	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	13	1	0	0	0	0	0	11
Kochia trichophylla	1	0	315	40	3	2	0	8	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Corispermum marginale	1	0	0	86	77	46	8	217	10	0	0	0	0	0
	2	0	17	17	18	18	0	0	0	0	0	0	0	0
	3	0	0	0	107	24	37	21	7	0	0	1	0	0
Atriplex hortensis	1	553	700	34	1	0	0	2	0	0	0	0	0	0
	2	0	22	8	2	1	0	0	0	0	0	0	0	0
	3	0	3	0	35	0	0	0	0	0	0	0	0	0
Atriplex hastata	1	641	0	22	0	0	0	0	0	0	0	0	0	0
	2	1	53	6	0	0	0	0	0	0	0	0	0	0
	3	0	4	0	20	0	15	0	0	0	0	0	0	0
Axyris amaranthoides	1	0	855	41	60	10	13	3	0	0	0	0	0	0
	2	0	176	49	0	2	0	1	0	0	0	0	0	0
	3	0	15	78	50	0	13	1	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Salsola Pestifer	1	0	951	304	280	23	1	68	3	0	1	0	0	0
	2	0	0	0	3	2	0	0	0	0	0	0	0	0
	3	0	0	0	2	0	0	0	0	0	0	0	0	0
Amaranthus retroflexus	1	0	0	71	134	342	253	373	30	10	123	0	3	2
	2	0	0	2	5	27	3	3	0	6	0	0	0	5
	3	0	0	6	9	35	74	75	4	11	3	0	0	2
Amaranthus blithoides	1	0	0	108	1155	286	27	269	6	0	3	0	0	0
	2	0	0	32	45	15	2	7	1	0	0	0	0	0
	3	0	0	7	20	18	46	76	4	0	0	0	0	0
Amaranthus graecizans	1	0	1	36	20	358	92	315	25	1	2	0	0	0
	2	0	0	1	5	4	5	0	1	0	0	0	0	0
	3	0	0	2	1	4	76	28	0	0	1	0	0	0
Portulaca oleracea	1	0	0	0	0	0	182	23	78	14	190	0	11	1
	2	0	0	0	0	7	33	9	2	3	0	0	0	0
	3	0	0	0	0	0	247	30	17	0	1	0	0	0
Spergula arvensis	1	0	22	20	8	17	0	178	1	2	0	1	0	0
	2	0	0	0	0	13	2	9	4	1	0	0	0	0
	3	0	0	0	30	0	33	3	0	1	0	0	0	1
Agrostemma githago	1	49	495	48	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene noctiflora	1	0	142	171	2	21	0	333	2	6	5	0	0	0
	2	0	6	8	3	1	0	0	0	0	0	3	0	0
	3	0	0	0	282	0	31	0	2	0	0	0	0	1

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Silene vulgaris	1	0	208	119	8	13	0	144	20	4	0	4	6	0
	2	0	5	4	3	0	0	0	0	0	0	0	0	0
	3	0	0	0	30	0	21	1	0	0	0	0	0	2
Vaccaria vulgaris	1	0	1137	377	33	6	0	22	1	0	2	9	6	0
	2	0	8	7	0	0	1	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidium perfoliatum	1	12	63	3	38	4	1	4	0	0	6	135	54	11
	2	0	1	0	2	0	0	0	0	0	0	1	0	7
	3	0	1	2	0	4	0	0	0	0	1	27	0	103
Lepidium densiflorum	1	0	95	12	113	8	14	42	7	9	34	77	48	2
	2	0	44	10	5	0	5	0	1	0	0	17	0	5
	3	0	3	55	0	1	65	28	9	6	4	0	0	44
Thlaspi arvense	1	0	1101	133	212	88	4	268	7	4	5	5	1	0
	2	0	166	52	23	65	7	2	2	3	0	0	0	19
	3	0	21	24	123	37	37	10	0	0	0	0	0	1
Capsella Bursa-pastoris	1	0	0	5	0	3	2	0	34	5	2	0	9	0
	2	0	0	0	0	14	5	2	1	0	0	1	0	0
	3	0	0	0	8	0	35	1	0	0	0	0	0	0
Camelina sativa	1	758	432	0	0	2	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Camelina dentata	1	1591	232	2	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Camelina microcarpa	1	1210	155	4	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Neslia poniculata	1	591	0	30	1	22	0	18	1	1	0	0	0	0
	2	0	3	1	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sisymbrium altissimum	1	0	790	26	139	4	1	3	0	0	16	0	31	0
	2	0	0	8	1	1	0	0	0	0	0	0	0	11
	3	0	132	121	11	11	14	24	1	0	1	0	1	9
Sophia multifada	1	0	45	4	28	13	1	23	0	2	2	113	9	0
	2	0	18	22	4	1	0	0	0	0	0	15	0	16
	3	0	0	14	1	0	3	7	2	0	0	29	13	45
Conringia orientalis	1	132	885	50	27	6	5	13	1	0	3	0	10	1
	2	0	7	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheirinia cheiranthoides	1	0	46	22	0	0	0	78	15	1	0	0	0	0
	2	0	3	1	1	1	0	1	1	0	0	4	0	0
	3	0	0	0	25	0	31	6	0	0	0	0	0	0
Sinapis arvensis	1	11	247	108	180	105	8	352	12	3	5	0	1	0
	2	0	19	38	3	6	1	1	1	6	0	2	0	3
	3	0	0	17	128	8	6	13	2	0	0	0	0	0
Erucastrum gallicum	1	0	157	7	15	47	2	130	19	7	1	1	1	0
	2	0	0	2	0	0	1	0	0	0	0	0	0	0
	3	0	0	0	0	0	21	7	0	1	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Brassica juncea	1	10	1025	95	16	13	0	62	2	1	0	0	1	0
	2	0	0	0	0	1	0	0	0	0	0	0	0	0
	3	0	0	0	4	0	1	0	1	0	0	0	1	0
Peritoma serrulatum	1	0	815	77	0	1	0	1	0	0	0	0	0	0
	2	0	211	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	1	0	2	0	0	0	0	0	0	0
Medicago lupulina	1	0	0	11	21	0	1	3	4	1	1	1	0	0
	2	0	302	93	2	3	1	0	0	0	0	0	0	0
	3	0	0	0	45	0	7	0	1	0	0	0	0	0
Oenothera strigosa	1	0	0	136	10	5	1	17	20	0	0	0	0	0
	2	0	0	32	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	14	3	0	0	0	0	0	0
Asclepias speciosa	1	0	0	136	54	5	10	6	22	0	0	0	0	0
	2	0	0	2	7	0	0	1	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Convolvulus americanas	1	0	1	14	18	2	2	4	5	2	1	3	4	0
	2	0	0	6	11	0	0	0	0	0	0	0	0	0
	3	0	0	2	5	13	2	0	0	1	0	0	0	0
Lappula echinata	1	0	516	67	63	6	1	93	4	3	0	2	0	0
	2	0	3	4	0	0	1	0	0	0	0	1	0	1
	3	0	6	7	2	0	2	0	0	1	0	0	0	0
Solanum triflorum	1	0	21	126	2177	6	19	1	0	0	0	0	0	0
	2	0	0	70	58	9	3	2	0	0	0	0	0	0
	3	0	0	8	11	6	0	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Plantago major	1	0	120	2	90	2	1	0	17	0	2	0	5	1
	2	0	0	1	6	5	0	14	1	0	0	0	0	0
	3	0	0	61	5	0	17	0	1	0	0	0	0	2
Cyclachaena Xanthifolia	1	0	84	36	10	0	0	0	0	0	0	0	0	0
	2	0	22	61	4	0	0	0	0	0	0	0	0	0
	3	0	1	25	12	5	1	0	0	0	0	0	0	0
Xanthium echinatum	1	0	52	351	5	4	0	11	2	0	0	0	0	0
	2	0	19	137	18	0	0	0	0	0	0	0	0	0
	3	0	0	0	5	0	0	0	0	0	0	0	0	0
Grindelia perennis	1	0	0	18	1	1	0	1	5	0	0	0	13	0
	2	0	34	5	3	11	0	0	0	0	0	16	0	8
	3	0	12	0	0	0	17	1	1	0	0	0	0	0
Helianthus aridus	1	0	872	164	538	4	1	2	0	0	0	0	0	0
	2	0	107	36	8	4	0	1	0	0	0	0	0	0
	3	0	1	11	17	0	3	0	0	0	0	0	0	1
Cirsium arvense	1	0	0	0	135	0	4	0	51	0	0	0	0	1
	2	0	0	1	2	1	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Tragopogon dubius	1	0	126	35	9	4	0	0	0	0	0	2	1	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum officinale	1	0	0	8	23	2	11	0	35	0	1	30	33	2
	2	0	7	3	0	0	0	0	0	0	0	4	0	0
	3	0	0	0	0	0	2	2	0	0	0	0	0	3

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Concluded*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Lactuca Scariola	1	0	102	1	0	0	28	0	0	2	0	37	4	0
	2	0	5	5	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	5	0	0	0	0	0	0	0	0	3
Lactuca virosa	1	0	157	13	117	1	3	0	7	1	1	6	38	1
	2	0	12	14	19	2	0	0	0	0	0	0	0	0
	3	0	0	87	0	1	0	0	0	0	0	0	0	0
Sonchus arvensis	1	0	0	0	93	2	1	0	37	0	0	0	1	0
	2	0	0	1	5	1	3	1	0	0	0	0	0	0
	3	0	0	4	0	0	1	2	1	0	0	0	0	0

followed by general tapering off in germination until midsummer or fall. In some species, particularly the winter annuals, the second peak, though in the majority of cases not as pronounced as the first, occurred in the fall.

The periodic and regular recurrence of germination, common to the majority of the species, was about the same on clay, loam, and sandy loam soil and was not entirely dependent on the variation in the moisture content of the soil. As an illustration, large numbers of seeds germinated early during the relatively dry springs of 1938, 1940, and 1941, but rains occurring during the same period in 1939, 1942, and 1944 failed to induce greater numbers of seeds to germinate and the trends in the frequency of germination within this period during each of these years remained essentially the same.

It was thought that alternate freezing and thawing during the winter months might stimulate the relatively high germination in the spring. This is not equally effective on all the species, for some germinated in substantial numbers late in the spring, others only during the summer months, and still others only in the fall of the year. There were some species, on the other hand, whose germination was more or less haphazard and showed no marked or regular periodicity, but the proportion of such species was relatively small. For some, the period during which substantial numbers or the majority of seeds germinated, was very short, but for others substantial numbers of seeds continued to germinate throughout the whole or most of the growing season. For the great majority of the species, the period or periods of high germination were apparently determined at the outset so that any variations in the weather had little, if any, influence on the actual behaviour of the dormant seeds.

In considering periodicity of germination it was thought desirable to deal with the naturally dormant seeds that will not germinate, even under most favourable conditions, apart from those that are physiologically ready to germinate as soon as moisture and other factors become favourable. Freshly harvested seed usually contains the two classes of seeds in widely variable proportions. The periodicity of germination was therefore determined for freshly harvested seeds containing the two physiological classes and for seeds that had lain in the soil for at least a period of one year. The emergence data (Table 4) indicate that periodicity of germination throughout the year after ripening follows the same general trend as that for seeds that have lain in cultivated soil for one or more years.

The species investigated can be classed into several broad classes with respect to periodicity of germination, as follows:

Species germinated in greatest numbers early in the spring (April 23 to May 15): *Agrostemma githago, Camelina microcarpa, Camelina sativa, Camelina dentata, Kochia trichophylla, Tragopogon dubius, Conringia orientalis, Brassica juncea, Salsola Pestifer, Lolium rigidum, Bromus tectorum, Bilderdykia Convolvulus, Hordeum jubatum, Agropyron repens, Lactuca virosa, Lappula echinata, Atriplex hastata, Peritoma serrulatum, Xanthium echinatum, Thlaspi arvense, Helianthus aridus, Lactuca Scariola, Sisymbrium altissimum, Cyclachaena xanthifolia, Axyris amaranthoides, Chenopodium album, Plantago major.*

Species germinating in greatest numbers usually in mid-spring (May 7 to May 31): *Setaria viridis, Rumex mexicanus, Cirsium arvense, Asclepias speciosa, Solanum triflorum, Sonchus arvensis, Corispermum marginale, Oenothera strigosa, Convolvulus americanus.*

Species with peak germination occurring between late spring and mid-summer (May 31 to August 31): *Amaranthus blithoides, Amaranthus retroflexus, Capsella Bursa-pastoris, Amaranthus graecizans, Portulaca oleracea.*

Species germinating most readily in the autumn (Sept.–Oct.): *Sophia multifida, Lepidium perfolatium.*

Species not showing any regular or marked periodicity: Erucastrum gallicum, Taraxacum officinale, Silene vulgaris, Sinapis arvensis, Spergula arvensis, Silene noctiflora, Grindelia perennis, Medicago lupulina, Cheirinia cheiranthoides, Monolepis Nuttalliana, Lepidium densiflorum.

The data in Tables 2 and 3 indicate the vitality of weed seeds as well as their longevity in cultivated soil. The data indicate that the ratio of seeds that germinated and emerged to the total number of seeds is very low on the whole but that there is a wide variation between the individual species. In most cases not over 50% of the seeds emerged and in many of these not over 10% emerged. The low emergence of seedlings may be attributed to any of the following causes: (1) dormancy of seeds, (2) low viability of seeds to begin with, and (3) high mortality of seedlings before or immediately after emergence.

In view of the characteristic tapering-off of germination towards the conclusion of the experiment and in many cases complete cessation of germination long before the experiment was terminated, it is evident that the generally low proportion of emergence is not particularly due to dormancy of seeds but to one or both of the other causes. Tables 2 and 3 include some information on the viability of seeds as determined by germination tests in very shallow layers of moist sand in the laboratory. The differences between the number of viable seeds and the total number of seedlings that grew in the field indicate the approximate number of seedlings that died before or immediately after emergence. For many species, however, the experiment has not yet been completed and for these the percentage of seedling mortality is so far unavailable.

Seeds of species used in these experiments were sown in rows in the field in order to observe and record such growth habits as date of maturity and resistance to shattering. These characteristics have a very important bearing on the relative seriousness of weeds and, from the standpoint of weed control, are closely associated with the length of seed dormancy and distribution of germination during the growing season. The data obtained from this study are presented in Table 5 and will be referred to later.

Although it was possible to classify the weeds into certain broad categories with respect to length of dormancy, nature of germination, vitality, and other physiological characteristics of seeds, there were nevertheless great differences between the individual species. In fact, the behaviour of seeds of any species was typical only of the species itself and not actually of the broad class they represent. Because of such wide differences in the behaviour of seeds of individual weeds, even of the same general class,

TABLE 5.—AVERAGE DATE OF MATURITY AND RESISTANCE TO SHATTERING OF GRAIN CROPS AND WEEDS IN THE FIELD (1938–1942)†

Species	Date of maturity *	Relative resistance to shattering	Species	Date of maturity *	Relative resistance to shattering
Triticum vulgare (Thatcher)	Aug. 10	100	*Lepidium densiflorum*	July 24	25
Avena fatua (Banner)	Aug. 8	85	*Thlaspi arvense*	July 7	35
Hordeum vulgare (Prospect)	July 26	95	*Capsella Bursa-pastoris*	July 15	35
Bromus tectorum	July 22	50	*Camelina sativa*	July 18	40
Agropyron repens	July 22	65	*C. dentata*	July 18	40
Lolium rigidum	Aug. 12	40	*C. microcarpa*	July 26	40
Hordeum jubatum	July 15	65	*Sisymbrium altissimum*	Aug. 7	40
Avena fatua	July 18	30	*Sophia multifida*	July 22	25
Setaria viridis	July 31	25	*Conringia orientalis*	July 23	45
Rumex mexicanus	July 18	65	*Cheirinia cheiranthoides*	Aug. 8	35
Polygonum neglectum	Sept. 25	55	*Sinapis arvensis*	July 21	40
Bilderdykia Convolvulus	Aug. 1	45	*Erucastrum gallicum*	July 31	40
Chenopodium album	Aug. 28	40	*Brassica juncea*	July 31	40
Monolepis Nuttalliana	Aug. 4	35	*Peritoma serrulatum*	Aug. 12	45
Kochia trichophylla	Sept. 13	45	*Medicago lupulina*	July 20	35
Corispermum marginale	Sept. 7	35	*Oenothera strigosa*	Aug. 16	40
Atriplex hortensis	Aug. 25	40	*Convolvulus americanus*	July 31	45
A. hastata	Aug. 16	40	*Solanum triflorum*	July 22	85
Axyris amaranthoides	Sept. 3	35	*Plantago major*	Aug. 15	25
Salsola Pestifer	Sept. 28	70	*Cyclachaena xanthifolia*	Sept. 8	45
Amaranthus retroflexus	Aug. 8	30	*Xanthium echinatum*	Aug. 19	85
A. blithoides	Aug. 10	35	*Grindelia perennis*	Sept. 20	40
A. graecizans	Aug. 22	35	*Helianthus aridus*	July 29	55
Portulaca oleracea	Aug. 2	25	*Cirsium arvense*	Aug. 12	50
Spergula arvensis	July 20	30	*Lappula echinata*	July 25	45
Agrostemma githago	Aug. 11	55	*Tragopogon dubius*	July 26	10
Silene noctiflora	July 24	30	*Traxacum vulgaris*	July 5	10
S. vulgaris	July 26	40	*Lactuca Scariola*	Aug. 10	25
Vaccaria vulgaris	July 24	40	*L. virosa*	Aug. 10	25
Lepidium perfolatum	July 22	35			

† Weeds were sown in rows 1 foot apart soon after ripening and grain crops were sown as soon as conditions for seeding became favourable the following spring.
* First seeds ripened and able to shatter. Grain crops ready to be cut with a binder.

it was thought appropriate to record the results of these experiments for each weed separately. The results obtained from the 3 series of experiments are treated together, however, to avoid undue repetition. The individual species are dealt with in order from the shortest to the longest average length of dormancy of seeds.

Species with None to Very Short Period of Seed Dormancy

Agrostemma githago (Table 4) shows no prolonged dormancy of seeds, all of which germinate early in the spring and within a period of one month. The data substantiate those of Muencher (11) and indicate that seeds can be plowed under to prevent immediate or subsequent emergence. The weed is a winter annual and as such gives trouble chiefly in winter crops. Because of early germination, field infestations can be prevented by delaying spring seeding until after-growth of seedlings have been destroyed.

Camelina microcarpa, *C. sativa*, and *C. dentata* all behave in much the same manner in the field (Table 4). They have a relatively short period of seed dormancy and seeds buried not deeper than 3 inches germinate

or rot before the end of June. Well over 95% of the seeds germinate particularly early in the spring, and because of this, may be induced to germinate early and be destroyed by tillage before spring crops are sown. Some plants of all three species behave as winter annuals and are therefore more serious in winter grains, particularly where tillage fails to destroy all existing plants. These weeds should not be a serious problem under clean cultivation. They are particularly common in poorly cultivated fields and in waste places where they are allowed to mature and shatter seeds (Table 5).

Kochia trichophylla (Fig. 1A) is an ornamental plant that has escaped cultivation, but apparently due to low degree of dormancy of seeds has never become a very serious weed. The great majority of the seeds germinate very early in the spring (Table 4) and the rest remain dormant for a period not exceeding 2 or 3 months.

Tragopogon dubius (Fig. 1B) has a maximum period of seed dormancy not exceeding one year. As with other weeds of this class, one year of clean, ploughless fallow should rid the land completely of dormant seeds. Due to low degree of seed dormancy, it is not a serious pest, and likely never will be in cultivated fields. It thrives well along roadsides, ditch banks, and abandoned fields were weeds are not destroyed.

Species with Short to Intermediate Average Period of Seed Dormancy

Conringia orientalis (Fig. 1C) and *Brassica juncea* (Fig. 1D). A few seeds of these two weeds live in shallow depths in cultivated soil for periods greater than one year (Tables 1, 2, and 3). Heavy infestations in crops succeeding fallow seldom occur, evidently because of low degree of dormancy of seeds. Their prevalence is often limited to edges of fields and roadsides where seedlings are not destroyed by cultivation. Seeds of these weeds shatter readily (Table 5) and germinate in large numbers early in the spring (Table 4). Heavy infestations can therefore be destroyed before a spring crop is sown.

Two seeds of *B. juncea* out of a total of over 5000 germinated in the fourth year after seeding. In order to find out if this extreme length of dormancy is transmitted to the progeny or not, the seedlings were allowed to reach maturity and 200 seeds tested for dormancy in the laboratory. All viable seeds germinated within one year, indicating that the exceptionally long period of dormancy of these seeds was not transmitted to the progeny.

Salsola Pestifer (Fig. 1E) shows a rather short period of dormancy for the great majority of the seeds, on an average not over 0.5% germinating in the second year and only 2 out of a total of over 5000 having been found to live near the soil surface for 3 years. In spite of its low dormancy *S. Pestifer* is very widespread in dry regions. This is due to characteristics other than dormancy of seeds. At maturity *S. Pestifer* breaks off at the base and blows away, scattering seeds as it travels with the wind. Wherever a thick stand of this weed is found, however, the plants are held together and do not blow away readily, and because seeds hardly shatter when the plants are not blown about, their vitality is preserved for many years. Such infestations serve as a continual source for soil pollution,

unless plants and seeds are destroyed by ploughing or burning. Ploughing to bury all the seeds deeply in the soil where they will not rot away without emerging has generally produced clean crops, but this treatment has some disadvantages. Burning is likewise effective but is dangerous in areas subject to erosion.

The great majority of *S. Pestifer* seeds lying on or just below the ground germinate early in the spring (Table 4). In controlling this weed advantage should be taken of this characteristic by allowing the seeds to germinate and destroying the seedlings before the crop is sown. It must be borne in mind, however, that unless all seeds are in contact with the soil, germination will be incomplete and tillage to destroy the seedlings prior to seeding may bring more seeds in contact with the soil where they will germinate and spring up in a crop. Ploughing under to bury the seeds, or to place them in a position where they will germinate and later be destroyed by tillage, should be a satisfactory method of eradicating this species, provided plants are not allowed to reach maturity and are not carried in from infested areas by the wind.

Vaccaria vulgaris (Fig. 1F) shows a comparatively low degree of seed dormancy. In the samples chosen for investigation 97% of the viable seeds germinated during the first year after seeding, 3% during the second, and only one seed out of a total of over 5000 germinated in the third year. Because of low dormancy of seeds, the weed, though widespread, does not persist in great numbers in cultivated fields.

Setaria viridis (Fig. 1G) has a relatively short period of seed dormancy, well over 98% germinating during the first year from shallow depth in the field (Tables 1, 2, and 3). The seeds do not germinate very early in the spring (Table 4) and for this reason heavy infestations may occur in early sown spring crops. The weed could be controlled by delaying the final shallow cultivation until after June 15 and then seeding the land to some early maturing crop such as barley. A clean summerfallow should be particularly effective in destroying heavy infestations of this weed.

According to Muencher (11) the seeds will not germinate in the fall of the year in which they are produced, but remain dormant until the following spring. The data presented herewith (Table 4) indicate that all seeds, those that have lain in cultivated soil for more than a year as well as newly shattered seeds, behave in this manner, for none have been observed to germinate after August 31 and only 4 out of a total of 2266 after July 31.

Rumex mexicanus (Fig. 1H) and *Cirsium arvense* (Fig. 1I) have seeds that possess a relatively short period of dormancy, though some may live in cultivated soil without germinating for 2 or 3 years. There is relatively little danger of these weeds persisting from seed infestations, but the problem with *Cirsium arvense* is due to the persistence of its perennial root system against cultivation and also against competition from other plants. *R. mexicanus* on the other hand, is not a serious weed, for its perennial roots can be readily destroyed by cultivation.

The seeds of both of these weeds germinate most readily in mid-spring (Table 4). The viability of seeds of both species was particularly low, for not over 5% of the seeds that were planted germinated (Table 3).

Lolium rigidum (Fig. 1J) shows a comparatively short period of dormancy of seeds, the majority of which grow or lose their viability in the soil within a year. Clean fallow should be quite effective in ridding the soil of most of the seeds. The majority of the seeds, if in contact with the ground, germinate early in the spring, that is, before May 15 (Table 4), and these could be destroyed before a spring crop is sown.

Asclepias speciosa (Fig. 1K) shows a period of seed dormancy not exceeding 2 years, although 95% or more of the seeds germinate during the first year. The seeds germinate in greatest numbers between May 7 and May 31 (Table 4), though fairly substantial numbers continue to germinate till about July 31, after which date germination ceases.

Bromus tectorum (Fig. 1L) seeds showed a variable period of dormancy in the samples chosen for investigation, although none lived at shallow depths in soil beyond a period of 3 years. The 1937 seeds all germinated and lost their viability in soil within a year (Table 1), but substantial numbers of the 1938 seeds, ranging from 25 to 50% of the total numbers that germinated, grew in the second year (Table 2). Less than 2% germinated during the third year after seeding.

Bromus tectorum seeds, if in contact with the ground, germinate in large numbers early in the spring (Table 4) and this behaviour can be taken advantage of by inducing the majority of the seeds to germinate and destroying the seedlings before a crop is sown. Substantial number of seeds also germinate in the fall and those plants that show a winter annual habit of growth will therefore survive into the next year, unless they are destroyed by cultivation. This weed produces seeds in abundance and from the standpoint of seed characteristics, has the potentiality of a moderately serious annual weed.

Bilderdykia Convolvulus (Fig. 1M) contains well over 95% of seeds that germinate during the first year and none remain viable in soil beyond a period of 3 years. The weed should be easily controlled by clean cultivation, but the difficulty is that the seeds are not much smaller than those of wheat and are therefore very difficult to remove from the grain. The seeds germinate in greatest numbers early in the spring (Table 4), hence many seedlings can be destroyed before a crop is sown.

Species with Long to Exceedingly Long Period of Seed Dormancy

Hordeum jubatum (Fig. 1N) and *Agropyron repens* (Fig 1O), though listed under two different classes with respect to period of seed dormancy, show little actual difference, the former falling at the bottom of one class (life in cultivated soil up to 3 years), the latter at the top of the next class (life in soil exceeding 3 years). Actually, seeds of *H. jubatum* originating in 1940 showed slightly longer average period of dormancy than those of *A. repens* (Table 3), though the reverse was true for seeds of the other two years (Tables 1 and 2). The seeds of the two species likewise differ little with respect to periodicity of germination, the peak germination in both occurring between April 23 and May 15 (Table 4).

Lappula echinata (Fig. 1P) does not indicate a particularly long average period of dormancy of seeds, 95% of which germinate during the first year. Clean summerfallow to rid the land of fresh infestations of seeds should be

very effective in ridding the soil of weed seeds. The great majority of the seeds, if in contact with the ground, germinate very early in the spring (Table 4) and these can be destroyed before a crop is sown.

Avena fatua (Fig. 1R). The seeds show a maximum period of dormancy of 3 to 4 years. The maximum period of dormancy is actually about one year shorter than for *Lappula echinata* but the percentage of seeds germinating in the second and third years is substantially greater. In these experiments, about 80% of the viable seeds germinated during the first year, 18% during the second, 2% in the third, and 2 seeds out of several thousands in the fourth year. Seeds originating from the secondary florets of a spikelet show greater tendency to dormancy than the larger seeds originating at the base of the spikelet. Cultivation to induce the seeds to germinate, followed by destruction of the seedlings, should be quite effective in ridding the soil of many seeds. The great majority of the seeds, if buried at shallow depths in the soil, germinate in May (Table 4) and these could be destroyed before a crop is sown. Contrary to most other weeds, wild oats seeds will not germinate readily when lying on the surface of the ground. It is essential therefore to work the land early, preferably immediately after the crop is removed to bury the seeds at a depth where they will most readily germinate.

Atriplex hortensis (Fig. 2A) and *A. hastata* (Fig. 2C) each have two distinct morphological types of seeds, type A exhibiting virtually no delayed germination and type B showing very marked longevity in cultivated soil. In *A. hortensis*, type A seeds are flat, light brown, about 3 mm. in diameter, usually enclosed in bracts at maturity. Those of type B are smaller but of variable size ranging from 1 to 2 mm. in diameter, more spherical, dark brown or black, usually without bracts or bracts falling off at maturity. *A. hastata*, on the whole, has much smaller seeds than *A. hortensis*. Seeds of type A are 1.5 to 2 mm. in diameter, flat and dark brown; those of type B are 0.5 to 1 mm. in diameter, black, and more spherical than those of type A.

The two types of seed were separated in samples originating in 1938, 1939 and 1940 and were subjected to repeated germination tests in the laboratory until no more would germinate. The following are the average results obtained:

Species	Type A seeds		Type B seeds	
	Viable seeds germinating within 6 months	Germinating after 6 months	Viable seeds germinating within 6 months	Germinating after 6 months
	%	%	%	%
A. hortensis	100.0	0	11.7	88.3
A. hastata	100.0	0	9.8	90.2

Seeds of type B were subjected to repeated germination tests for 3 years but so few germinated during this period that it was decided to treat them with concentrated sulphuric acid in order to disintegrate the

outer seed coat to facilitate germination. The seeds were immersed in the acid for 15 minutes, after which treatment all viable seeds germinated immediately.

There were about equal proportions of the two types of seeds in the samples examined. If *Atriplex* possessed type A seeds only, it would be classed as a species showing little or no seed dormancy, but if it had type B seeds only, the state of dormancy would be of the highest order.

No attempt was made to separate the two types of seed in field experiments, hence the results obtained on the length of dormancy indicate an approximate average for the mixture of these two types. The data indicate that some seeds, evidently belonging to morphological type B, are capable of remaining dormant in cultivated soil for at least a period of 5 years, but it is evident that the maximum length of dormancy for some of the seeds is greater than this period. Of the weeds so far considered in this report, *Atriplex* spp. are the first whose maximum period of dormancy extends beyond a period of 5 years.

Polygonum neglectum (Fig. 2B) has a substantial proportion of seeds germinating after lying in cultivated soil for more than 1 year. The maximum concentration of germination occurs within a limited period between April 23 and May 15 (Table 4). No germination occurs under any circumstance after June 30.

Erucastrum gallicum (Fig. 2D) possesses seed dormancy similar to that of *Polygonum neglectum*, but does not show the same regular nor marked periodicity of germination. Most of the seasonal emergence occurs between April 23 and July 15 (Table 4), but no definite peak of germination is evident in this species. A few seedlings continue to emerge right through till the end of September.

Peritoma serrulatum (Fig. 2E) has a particularly high proportion of seeds germinating after lying in cultivated soil for a year. The seeds have a very sharp peak of germination occurring between April 23 and May 15 (Table 4), and no seeds germinate after July 15.

Taraxacum vulgaris (Fig. 2F). The samples obtained for experiment show a maximum period of seed dormancy of only 4 years, but the proportion of viable seeds germinating during the third and the fourth years is much higher than in any of the species so far considered, including those having some seeds that germinate during the fifth year. The average period of seed dormancy, as determined, is therefore higher for this than for any of the other species so far discussed. The seeds show no regular or marked periodicity of germination (Table 4).

Xanthium echinatum (Fig. 2G), has a few seeds germinating during the fifth year after seeding (Table 3) and it is likely that some will survive even beyond this period. The peak of germination occurs between May 1 and May 15 (Table 4), though emergence of relatively few seedlings continues till about the end of July, after which date seeds do not germinate until the following spring.

Sonchus arvensis (Fig. 2H) and *Lactuca Scariola* (Fig. 2L) have little in common except that seeds of both exhibit an approximately equal relative length of dormancy in cultivated soil. Seeds of *S. arvensis* begin

germinating usually in mid-spring with a considerable proportion of seedlings appearing till about the end of July (Table 4). *L. Scariola* begins germinating on the whole about 2 weeks earlier and, in addition to its peak germination in the spring, has the second peak, though not as pronounced as the first, occurring in the fall (Table 4). The tendency of seeds to germinate in the fall appears to be typical of most winter annuals. *L. Scariola* appears to possess seeds of greater relative period of dormancy than *L. virosa* (Fig. 1Q), though this may be due to the difference between the two samples of seed used rather than the general rule.

Seeds of *S. arvensis* and *L. Scariola* on the whole possess a relatively low viability of seeds (Tables 2 and 3).

Solanum triflorum (Fig. 2I) and *Helianthus aridus* (Fig. 2J) show longevity in cultivated soil similar to that of *Sonchus arvensis*, but the behaviour of the seeds with respect to seasonal germination is very different in each case. The seeds of *S. triflorum* germinate in greatest numbers between May 1 and May 31 and none after July 31 (Table 4). Those of *H. aridus* have their peak germination earlier in the spring and as with *S. triflorum* seldom germinate after July 15.

Thlaspi arvense (Fig. 2K). The data indicate that few, if any, seeds live in cultivated soil beyond a period of 6 years. Substantial numbers in most samples, however, germinate throughout the first 4 years after seeding. This characteristic behaviour is typical of the most serious annual weeds, for no treatment however effective in suppressing or destroying the vegetative growth would be at all effective in destroying the seeds that are already present in the soil, unless such treatment is continued for many years.

Much and sometimes the largest proportion of the seasonal emergence of *T. arvense* occurs before the middle of May (Table 4) and this could be destroyed before a crop is sown. However, many other seedlings continue to emerge after this date and right through to the end of the growing season. The growth of the weed in a crop is therefore liable to be heavy unless a thick vigorous stand of the crop is established before many weeds emerge.

The data indicate (Table 5) that seeds of this species mature and shatter long before a grain crop is harvested. This is a serious characteristic and is undoubtedly largely responsible for such widespread occurrence of the weed.

Silene vulgaris (Fig. 2M) and *Sinapis arvensis* (Fig. 2N) have substantial numbers of seeds that germinate from cultivated soil throughout the first 4 years after seeding and longevity of the remaining seeds extend for at least 6 years. The seeds germinate in large numbers early in the spring (Table 4) but, as with *Thlaspi arvense*, a substantial proportion of them continues to germinate after this period and right through until fall. Both weeds produce seeds in abundance which mature and shatter in large numbers before crops are harvested (Table 5). From the standpoint of volume of seed production, seed dormancy, periodicity of germination, and seed shattering, these species have characteristics of particularly serious weeds.

Sisymbrium altissimum (Fig. 2O). Relatively few seeds of this species remain dormant in cultivated soil for periods greater than 6 years. The peak of germination occurs early in the spring (Table 4) and this aids in destruction of large numbers of seedlings before a crop is sown. As indicative of all winter annuals, another peak of germination, though not as pronounced as the first one, occurs in the fall.

The weed is a very prolific seeder, but seedlings are so tender that many, perhaps the great majority, die before growth is finally established. Unlike those of *Sinapis arvensis*, the seedlings cannot stand much competition with a cereal crop, although they can compete somewhat more successfully in dry years.

Axyris amaranthoides (Fig. 2P) has two distinct morphological types of seed, type A exhibiting little delayed germination and type B showing very marked longevity in cultivated soil. Type A seeds are oblong, tapering at the base, brown, with surface minutely wrinkled and giving a speckled appearance, and a distinct ear or wing on the upper end. Those of type B are somewhat smaller, oval to almost round, greyish, with a smooth surface exhibiting a silky lustre.

The two types of seed were separated in samples originating in 1937 to 1940, inclusive, and subjected to repeated germination tests in the laboratory for a period of 4 years. The following are the results obtained:

GERMINATION OF TYPE A AND TYPE B RUSSIAN PIGWEED SEEDS IN MOIST SAND IN THE LABORATORY

Seeds germinating in	Type A		Type B	
	Viable seeds germinating within		Viable seeds germinating within	
	6 months	2 years	6 months	3 years
	%	%	%	%
1937	77.6	100.0	0	14.3
1938	98.5	100.0	0	0
1939	84.6	100.0	0	0
1940	92.9	100.0	0	31.8

The majority of type A seeds germinated immediately, that is, within 2 weeks after being placed in a layer of moist sand 1 cm. thick. None of these seeds remained viable in moist sand beyond a period of 2 years and in fact all but those of 1937 germinated within 12 months from the start of the test. None of type B seeds, on the other hand, germinated within 1 year of exposure in moist sand and only 14 out of a total of 800 germinated within a 3-year period, those germinating belonging to the 1937 and 1940 lots. At the end of the 3-year period type B seeds were immersed in concentrated sulphuric acid for 15 minutes as a result of which treatment all the seeds that remained viable germinated immediately. It is believed, however, that many and perhaps the majority of the seeds, which might have in time germinated in moist sand, were killed by the acid treatment.

If so, the percentage in the second column under type B seeds would even be lower than indicated, since germination percentage is based on the total germination and not on the numbers of seeds taken for experiment.

In field tests, no attempt was made to separate the two types of seed, hence the results obtained indicate average results for the mixtures in question. In the samples examined, the proportion of type A seeds was found to vary from 54 to 71%.

Field data (Table 2) indicate that many seeds, evidently belonging to morphological type B, are viable after lying in cultivated soil for 6 years. From the standpoint of weed control this is a serious characteristic, but it is compensated by other factors that appear to reduce considerably the seriousness of the weed. The proportion of highly dormant seeds to the total number is relatively small. In addition, it possesses a very sharp peak of germination occurring before May 15 (Table 4), thus facilitating the destruction of a great proportion of total seasonal emergence of seedlings before a crop is sown. Furthermore, seeds mature quite late in the season (Table 5), thus the crop and the weeds are often cut and removed before any weed seeds shatter. For this reason, the weed thrives better along edges of fields, roadsides and waste places where plants are less likely to be destroyed before maturity.

Spergula arvensis (Fig. 2 Q) and *Silene noctiflora* (Fig. 3A) both show very long dormancy of seeds. They are very prolific seeders and mature and shatter large quantities of seeds before a crop can be harvested (Table 5). They appear to have many characteristics of serious annual weeds. Both show marked fluctuations in germination, but do not show any regular periodicity of germination (Table 4). The largest proportion of season emergence occurs between April 23 and July 31. The lack of a definite cycle of germination renders them difficult to cope with, for no definite tillage or cropping practice can be expected to produce the same effect in every year.

Oenothera strigosa (Fig. 2R) though possessing a high degree of seed dormancy, is a biennial and as such is not a serious weed in cultivated crops. Large numbers of seeds begin to germinate in mid-spring (Table 4), though a fair proportion of them continue to germinate till about July 31, after which date germination ceases. This species is the first case of a weed possessing highly dormant seeds but giving little trouble in cultivated fields, the reason for this being the biennial habit of growth.

Cheirinia cheiranthoides (Fig. 3B) has seeds capable of remaining dormant in cultivated soil for many years and hence has potentialities of a serious annual or winter annual weed. It possesses a few characteristics that facilitate its control in spring crop areas. Though some seeds germinate about the time the crops are sown, large numbers germinate later in the season (Table 4) and as seedlings are particularly small and fragile in the early stages of their development, they are readily suppressed by a vigorous crop. The period of emergence to ripening for this species is about the same as for wheat (Table 5); therefore the great proportion of weed seeds may be gathered up with the grain before they have had a chance to shatter. Apparently, because of these habits, it is more common along roadsides and waste places than in well cultivated fields.

Amaranthus graecizans (Fig. 3C), *A. retroflexus* (Fig. 3D), and *A. blithoides* (Fig. 3E) all possess very long dormancy of seeds, many of which do not "grow out" from shallow depths in the soil within 6 years. The seeds of all three possess a very thick, hard coat which is permeable to water but remains dense and brittle in the soil for many years, even after the embryo has split it open when germinating.

Fortunately these species are not as serious as the period of seed dormancy might indicate, mainly because of one outstanding feature. The seeds, particularly of the latter two species, do not germinate in appreciable numbers until late spring or summer (Table 4) and by that time the crops have made considerable growth and are able to compete successfully with any weeds that might emerge. They often become serious pests where competition from crop is poor or lacking, such as in gardens or edges of cultivated fields. They do not mature seeds early (Table 5) but often grow and produce large supplies of seed in stubble after the crop is removed. They are particularly prevalent on fallowed land, for they emerge in large numbers after other weeds have ceased to germinate, thus necessitating additional tillage to keep them down. Where such growth is light, farmers are inclined to leave the summerfallow unworked and through such procedure—or lack of procedure—allow a few plants to produce large numbers of seeds. It must be pointed out that all three, if allowed to reach maturity, produce abundant numbers of highly viable seeds (Tables 2 and 3).

Corispermum marginale (Fig. 3F) has a very long period of dormancy in cultivated soil but for some reason yet unknown does not cause serious damage to cultivated crops, except on sandy soils. It thrives particularly well in dry conditions, and on soils subject to wind erosion has perhaps been as great an asset as a liability by being able to cover the surface and protect it from the ravaging effects of the wind. It begins germinating usually in mid-spring and keeps on germinating in substantial numbers till about July 31 (Table 4).

Cyclachaena xanthifolia (Fig. 3G) is another case of not exceptionally serious weed possessing a high degree of seed dormancy. It matures late in the season (Table 5), thus facilitating its removal along with the crop before any seeds shatter on the ground. Plants along the edges of the fields, however, are not often destroyed and reach maturity. Hence, this species is found more generally along roadsides and edges of fields than in cultivated crops. The seeds germinate in large numbers early in the spring and these can be destroyed before the crop is sown. No germination has been observed to take place after June 30 (Table 4), hence tillage to facilitate fall germination would be futile.

Sophia multifida (Fig. 3H) has many characteristics of a serious annual weed. It has an especially long period of dormancy of seeds, germinates in large numbers just about the time the crops are sown (Table 4) is a prolific seeder, matures early and shatters readily (Table 5). It is a very common weed in western Canada and will no doubt continue to be so for a long time, for no program however effective in destroying or suppressing the growth of the weed will be at all effective in destroying the seeds that are already present in the soil. The weed cannot compete with grain crops quite like *Sinapis arvensis*, for example, and where feasible can be

controlled by heavy seeding of grain and by use of commercial fertilizers (9). It germinates in large numbers in the fall (Table 4) in which case the seedlings must be destroyed before the next crop is sown.

Chenopodium album (Fig. 3I) has many seeds of comparatively long periods of dormancy in cultivated soil and is a prolific seeder. It is therefore a serious weed once the soil becomes heavily polluted with weed seeds. It has certain characteristics, however, that tend to prevent soil pollution and because of these the weed is only of secondary importance to such annual weeds as *Avena fatua*, *Sinapis arvensis* and *Thlaspi arvense*, all of which shatter large quantities of seed before the crop is harvested. Unlike these weeds, *C. album* matures rather late in the season (Table 5) and the weed can be harvested along with a crop before many weed seeds have had a chance to shatter. The weed often grows and develops in stubble after the crop is cut, hence cultivation immediately after harvest is essential for its control. Where land is heavily polluted with weed seeds, relatively large numbers of seedlings can be destroyed before a crop is sown, for these begin germinating early in the spring (Table 4). However, the destruction of weeds before seeding is in itself not an assurance of a clean crop for as in the case of *Thlaspi arvense* and *Sinapis arvensis*, comparatively large numbers continue to emerge well into the month of July. Where feasible, fertilizing to produce a vigorous crop that would compete effectively with the weed, is a useful practice (9).

Plantago major (Fig. 3J) indicates a very long period of dormancy of seeds. It is, however, not a very serious weed in Canada. The weed possesses a relatively shallow perennial tap root that is readily destroyed by cultivation, usually before seeds are produced. It is therefore common in old pastures, meadows, lawns and waste places and is more prevalent in humid than in dry regions. *P. major* begins to germinate early in the spring, but a fair proportion of seeds continue to germinate throughout most of the growing season (Table 4).

Lepidium densiflorum (Fig. 3K) and *L. perfoliatum* (Fig. 3L) have certain common physiological as well as botanical characteristics. Seeds of both possess great longevity in cultivated soil, both are very prolific seeders, reach maturity early (Table 5), and shatter large quantities of seed before the crop is cut. *L. densiflorum* is very common in Canada and is responsible for substantial reductions in crop yields. It does not compete successfully with a really vigorous crop, however, and methods that favour rapid development of the crop have a definite advantage in suppressing this weed. *L. densiflorum* germinates at a more or less uniform rate throughout the whole of the growing season (Table 4).

L. parfoliatum was recently introduced from Europe and is spreading rapidly. It is potentially even more serious than *L. densiflorum* for it is taller, develops more rapidly, and competes more effectively with grain crops. Its peak germination occurs in the fall (Table 4), and since it is a winter annual it is essential that this late fall growth be destroyed before the next crop is sown.

Capsella Bursa-pastoris (Fig. 3M) does not appear to have a large proportion of seeds remaining dormant in cultivated soil beyond a period of 5 years, but does indicate a comparatively high emergence in the third

and fourth years. For a prolific and early seeder (Table 5) this is a serious characteristic, but in spring crop areas it has one drawback that forces it to fall into a class of secondary economic importance. It has a peak germination occurring in the late spring or summer (Table 4), hence its emergence coincides with a period when crops have generally become well established and able to compete successfully with this weed. It is therefore more common in areas that offer less competition to its development, such as in gardens, farmyards, and uncultivated fields.

Grindelia perennis (Fig. 3N) has a high degree of dormancy of seeds, but is a biennial or a short-lived perennial that readily succumbs to clean cultivation methods. Because of this habit of growth, it is unable to produce seeds before plants are destroyed by tillage. It is therefore a weed common to the native prairie, roadsides and uncultivated fields. *G. perennis* does not appear to possess any marked or regular periodicity of germination (Table 4).

Portulaca oleracea (Fig. 3O) has a very long period of natural seed dormancy so that land once infested with it may be expected to remain infested for many years, even under clean cultivation. It cannot compete successfully with spring grain crops, however, but is common mostly in gardens and orchards that offer less competition for its development. The plants are small and seedlings do not emerge until after June 15 (Table 4) by which time grain crops have made considerable growth to enable them to smother it completely. *P. oleracea* grows and matures late in the season (Table 5), hence it is important to continue removing and destroying all young plants until fall.

Medicago lupulina (Fig. 3P) like other members of *Medicago* contains some hard seeds that are capable of remaining dormant in cultivated soil for many years. It does not appear to reduce the yield of grain crops considerably, however, and thrives more commonly on somewhat infertile soils. *M. lupulina* has a distinct peak of germination which is not particularly regular in its occurrence (Table 4). A fair proportion of seedlings, however, occur throughout most of the growing season.

Monolepis Nuttaliana (Fig. 3Q), like *Chenopodium album* with which it is distantly related, possesses a comparatively high degree of dormancy of seeds, many of which germinate only after lying in soil for 4 or 5 years. The plants are low and do not appear to offer much competition to growing crops. This weed possesses no marked or regular periodicity of germination (Table 4). It matures relatively late in the season (Table 5) and for this reason does not shatter many seeds before the crop is cut.

Convolvulus americanus (Fig. 3R) has hard seeds that remain viable in soil for long periods and only a small proportion of which germinate in any one year. In one experiment (Table 1), 88.7 per cent of the viable seeds lay at shallow depths in cultivated soil for 3 years without germinating. In another experiment (Table 2) 55.2% of the total numbers that germinated lay dormant in the soil for 6 years. It is evident that the maximum period of dormancy in cultivated soil is much greater than 6 years. As in all species containing hard seeds, emergence of seedlings appears throughout most of the growing season, although in this species the peak of germination occurs in mid-spring (Table 4).

DISCUSSION

The data obtained from this investigation indicate that weeds differ greatly with respect to germination and habits of growth. It can be concluded therefore that no method of attack, however effective on one weed, would be equally, if at all, effective on another. For the man on the land this complicates the problem considerably for very few cases can be cited where the weed problem is due entirely to some one particular weed.

The relative seriousness of a weed is due principally to any one or several of the following characteristics:

Period of dormancy of seeds.
Distribution of germination throughout the growing season.
Viability of seeds.
Quantity of seeds produced.
Date of maturity.
Resistance to shattering.
Method of seed distribution.
Ability to compete with growing crops.
Persistance of perennial roots under cultivation.

Detailed information with respect to the first three characteristics is presented in this paper for 58 of the most common species. Somewhat more limited information is also presented on date of maturity and shattering quality, both of which are closely associated with the period of seed dormancy and nature of seasonal germination. Consideration of the remaining factors is beyond the scope of this paper. The point that is brought out clearly from this investigation is that dormancy of seeds, though not entirely responsible for the seriousness of a weed, is nevertheless one of the most important factors. Of all annual weeds presenting real economic difficulty only one, *Salsola Pestifer*, possesses a relatively short period of dormancy of seeds. This weed, though serious in dry regions, is relatively easy to control. Its seriousness is as much, if not more, due to its rapid growth and development in stubble *after* a crop is removed, as to direct competition with the growing crop. Its widespread occurrence is due principally to its high drought resistance and particularly rapid distribution by the wind.

There is no practical method known at present that will eradicate weeds of relatively long period of dormancy of seeds. Where weeds of this nature are encountered, it is evident that stress should be laid on tillage and cropping practices that favour the growth of the crop and suppress the vigour and density of the weeds rather than on methods that are designed to destroy the weed seeds in the soil. The summerfallow, which is particularly effective in destroying weed seeds of relatively short period of dormancy, can be regarded as only partially effective or entirely inadequate on seeds of long period of dormancy. This is because clean summerfallow, though effective in reducing the total numbers of viable seeds, will not destroy many others which, if conditions are suitable, are capable of producing a density of growth sufficient to smother the crop.

On the other hand, a periodic use of clean summerfallow, combined with practices that prevent the reinfestation of the soil with weed seeds, may in time reduce the numbers of viable seeds in the soil do a degree

that would constitute no serious menace to cultivated crops. Much of our agricultural land, however, is so badly infested with seeds of long period of dormancy that it would take many years, even if weeds were not allowed to produce seed, before clean crops could be grown.

The data obtained from this study indicate the relative longevity of weed seeds in soil under a tillage and cropping treatment such as generally practised in the dry prairie region of western Canada, except that plants were all destroyed to prevent re-infestation of the soil. The data do not necessarily indicate the induced or the natural periods of dormancy of seeds, but are nevertheless of practical significance for they show the behaviour of weed seeds under conditions as generally exist in cultivated land.

SUMMARY

Studies were initiated in 1937 on the relative length of dormancy, frequency of seasonal germination, vitality, and other physiological characteristics of seeds of weeds common to Western Canada. Samples of weed seeds have been taken for several years and mixed into a 2.5-inch layer of sterilized soil in the field. The soil was periodically cultivated to 3-inch depth and was kept in fallow one year and sown to spring wheat or barley in alternate years. Records of seedlings were made as they appeared.

Analyses of the data obtained show that seeds of different species differ widely in their behaviour in cultivated soil and that they could not be classified into categories showing common physiological characteristics. It was concluded that no method of attack, however effective on one weed, would be equally effective on another, for each species possesses a set of its own particular characteristics. Because of this, the results of these experiments were recorded separately for each species.

The results indicate that most species contain some seeds that germinate immediately after they are placed under favourable conditions, but that a proportion of the remaining seeds lie dormant for various periods. In some species the length of period required for all seeds to germinate, known as the *maximum* period of dormancy, is only a month or two, in others many years.

The *average* period of seed dormancy was also determined. It was found that seeds of species, even with the same maximum period of dormancy, show marked differences in the average period of dormancy. For the purpose of weed control, information on the average period of dormancy is more important, but from the point of view of weed eradication the maximum period of dormancy is of paramount importance.

Out of a total of 58 species, 6 were found to have seeds whose life span in cultivated soil does not exceed 1 year and 18 were found to have seeds whose life span usually does not exceed 3 years. With two exceptions, none of these species are particularly serious weeds. The majority of other weeds that possess periods of seed dormancy lasting many years constitute a serious agricultural problem and it is therefore concluded that the relative period of seed dormancy is one of the greatest single factors contributing to the seriousness of a weed.

Clean fallow is particularly effective on weeds with relatively short period of seed dormancy but is only partially effective or entirely inadequate on weeds with relatively long period of seed dormancy, for many seeds lying dormant during the fallow year are capable of germinating in subsequent years and in sufficient numbers to suppress the growth of crops.

With most species there is a typical seasonal periodicity of germination throughout the life span of seeds. The period of maximum or peak germination varies with the species and there is no period within the growing season when seeds of some species do not show a substantial emergence. The relationship between periodicity of germination and the relative seriousness of a weed is recorded in numerous individual cases.

The periodic recurrence of germination does not seem to be affected by soil texture nor the amount of seasonal rainfall, but is apparently determined at the outset for the great majority of the seeds.

The ratio of seeds that germinated to the total numbers of seeds added to the soil was found to vary greatly with the species. The data indicate that with most species the ratio is very low, which is due in some cases to low viability of seeds and in others to high mortality of seedlings before and immediately after emergence in the field.

The influence of date of maturity and shattering quality of seeds on the relative persistence of a weed is pointed out in many cases.

ACKNOWLEDGMENTS

The author is indebted to A. C. Budd and F. Bisal for laborious recordings connected with this investigation.

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